This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

**Usage guidelines**

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

**About Google Book Search**

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

# SYLLABUS ON

# VERTEBRATA

COPE

Edwd. D. Cope

**Publications**
OF THE
**University of Pennsylvania.**

[illegible]

[illegible]

# Syllabus of Lectures
ON THE
# VERTEBRATA

BY

EDWARD D. COPE, Ph. D.,

Late Professor of Zoology and Comparative Anatomy in the
University of Pennsylvania.

With an Introduction by

HENRY FAIRFIELD OSBORN, Sc. D.,

Da Costa Professor of Zoology in Columbia University.

PHILADELPHIA:
PUBLISHED FOR THE UNIVERSITY OF PENNSYLVANIA.
1898.

*Press of Levytype Co., Engravers and Printers, Philadelphia.*

# THE LIFE AND WORKS OF COPE

## ILLUSTRATING THE TRAINING OF A NATURALIST AND THE ESSENTIAL CHARACTERISTICS OF A GREAT COMPARATIVE ANATOMIST.

BY HENRY FAIRFIELD OSBORN.

---

The work of Professor Cope began in 1859, a most favorable year, when Comparative Anatomy first felt the impetus of Darwin's "Origin of Species." He was then only nineteen, and for thirty-eight years thereafter his active genius hastened our progress in the knowledge and classification of all the great divisions of the Vertebrata.

He passed away upon April 12th, 1897, at the age of fifty-seven, in the full vigor of his intellectual powers, leaving a large part of his work incomplete. Almost at the last he contributed several reviews to the *American Naturalist*, and upon the Tuesday preceding his death he sent to the press this *Syllabus* of his Lectures before the University of Pennsylvania, containing his latest opinions regarding the arrangement and evolution of the Vertebrata. It seems appropriate in this posthumous edition of the Syllabus, issued by the University, to give a brief account of such incidents in Professor Cope's life as are worthy of imitation by coming generations of students; also to set forth some of the monumental features of his contributions to Comparative Anatomy.

The most conspicuous feature of his character from boyhood upwards was independence; this was partly the secret of his venturesome and successful assaults upon all traditional but defective systems of classification.

As a comparative anatomist he ranks both in the range and effectiveness of knowledge and ideas with Cuvier and Owen. When we consider the short life of some of the favorite generalizations of these great men he may well prove to be their superior as a philosophical anatomist. His work, while inferior in style of presentation, has another quality which distinguishes that of Huxley—namely, its clear and immediate perception of the most essential or distinctive feature in a group of animals. As a natural philosopher, while far less logical than Huxley, he was more creative and constructive, his metaphysics ending in theism rather than agnosticism.

Cope is not to be thought of merely as a specialist. After Huxley he was the last representative of the old broad-gauge school of anatomists and he is only to be compared with members of that school. His life-work bears the marks of great genius, of solid and accurate observation as well as of inaccuracy due to bad logic or haste and over-pressure of work. Although the greater number of his Natural Orders and Natural Laws will remain as permanent landmarks in our science a large part of his systematic work will require laborious revision and is thus far from standing as a model to the young zoologist.

In mere mass of production Cope's work was extraordinary. He leaves twenty octavo and three great quarto volumes of collected researches. By his untimely death a wide gap is left which can never be filled by one man.

## BIOGRAPHICAL.

Edward Drinker Cope was born in Philadelphia, July 28th, 1840, of distinguished American ancestry. His great-grandfather, Caleb Cope, was the staunch Quaker of Lancaster, Pa., who protected Major Andre from mob violence. Thomas Pim Cope, his grandfather, founded the house of Cope Brothers, famous in the early mercantile annals of Philadelphia. His father, Alfred, the junior member of this firm, was a man of very active intellect, and showed rare judgment in Edward's education.

Together the father and son became brisk investigators, the father stimulating, by questions and by travel, the strong love of Nature and of natural objects which the son showed at an unusually early age. In August, 1857, they took a sea voyage to Boston, and the son's journal is full of drawings of jellyfish, grampuses and other natural objects seen by the way. When eight and a half years old he made his first visit to the Museum of the Academy of Natural Sciences, "on the 21st day of the 10th Mo., 1848," as entered in his journal; he brought away careful drawings, measurements and descriptions of several larger birds, but especially the figure of the entire skeleton of an Icthyosaur, with this quaint memorandum: "Two of the sclerotic plates look at the eye—thee will see these in it." At the age of ten he was taken upon a longer voyage to the West Indies. It is not improbable that these voyages exerted a lasting influence upon him.

The principal impression he gave in boyhood was of incessant activity in mind and body, of quick and ingenious thought, reaching in every direction for knowledge, and of great independence in character and action. It is evident that he owed far more to the direct study of Nature and to his own impulses as a young investigator than to the five or six years of formal education which he received at school. He was especially fond of map drawing and of geographical studies. His natural talent for languages may have been cultivated in some degree by his tutor, Dr. Joseph Thomas, an excellent linguist, editor of a biographical dictionary. Many of his spare winter hours were passed at the Academy of Natural Sciences. After the age of thirteen the summer intervals of boarding-school life and later of tutoring were filled among the woods, fields and streams of Chester County, Pa., where an intimate knowledge of birds was added to that of batrachians, reptiles, and insects. He showed a particular fondness for snakes. One of these excursions, taken at the age of nineteen, is described in a letter to his cousin (dated June 24, 1859), in which, at the close of a charming description of the botany of the region, appears his discovery of a new type:

"I traced the stream for a very considerable distance upon the rocky hillside, my admiration never ceasing, but I finally turned off into the woods towards some towering rocks. Here I actually got to searching for Salamanders and was rewarded by capturing two specimens of species which I never saw before alive. The first (*Spelerpes longicauda*) is a great rarity here. I am doubtful of its having been previously noted in Chester County. Its length is 6 inches, of which its tail forms nearly four. The color is deep brownish yellow, thickly spotted with black, which becomes confluent on the tail, thus forming bands. To me a very interesting animal—the type of the genus *Spelerpes*, and consequently of the subfamily Spelerpinæ, which I attempted to characterize in a paper published in the Proceedings of the Academy of Natural Sciences. I send thee a copy, with the request that thee will neither mention nor show it,* for—however trifling—I would doubtless be miserably annoyed by some if thee should. Nobody in this country (or in Europe, of *ours*) knows anything about Salamanders, but Professor Baird and thy humble coz., that is, in some respects. Rusconi, the only man who has observed their method of reproduction, has written enough to excite greatly one's curiosity and not fully satisfy it. With suitable appliances of aquariums, etc., I should like to make some observations. The other Salamander I caught was *Plethodon glutinosum*—the young—remarkable for the great number of teeth that lie together in two patches on the 'basisphenoid' bone; about 300 or more."

Another passage gives an insight into his strong opinion, so often expressed afterward, as to what constitute the real pleasures of life:

"Pleasant it is, too, to find one whose admiration of nature and

---

*This passage probably indicates that he was sensitive to being laughed at for his interest in these animals.

**detail is heightened, not chilled, by the necessary 'investigation'—which, in my humble opinion is one of the most useful as well as pleasing exercises of the intellect, in the circle of human study. How many are there who are delighted with a 'fine view,' but who seldom care to think of the mighty and mysterious agency that reared the hills, of the wonderful structure and growth of the forests that crown them, or of the complicated mechanism of the myriads of higher organisms that abound everywhere; who would see but little interesting in a fungus, and who would shrink with affected horror from a defenseless toad * * * Dr. Leidy is getting up a great work on comparative anatomy which is to be the modern standard. Such a work will be very useful to those who want to go to the bottom of natural history; it is an interesting study, too, to notice the modification in form—the degradations,† substitutions, etc., among the internal organs and bones. The structure, forms and positions of teeth, too, are interesting to notice—so invariably are they the index of the economy and the position in nature of the animal.''**

This is the reflection of a lad of nineteen, an age at which some modern educators would have us believe our young men are just ready for the collegiate Freshman class. It is obvious from other portions of the letter that by this time young Cope's career was fully determined in his own mind. During the same year he went to Washington to study and work in the Smithsonian Institution under Spencer F. Baird, and it is amusing to observe him in the above letter classing himself with Baird as the only Americans who knew anything of the Batrachia.

Upon April 19, 1859, he contributed his first paper (alluded to above) to the Academy "*On the primary divisions of the Salamandridæ, with a description of two new species.*" He followed this by a full description, in the same year, of reptiles brought from West Africa by Du Chaillu, naming several new forms; also by a catalogue of the venomous snakes in the museum. In the succeeding three years he

---

†A word used by French writers of the time to express lines of evolutionary descent.

made twenty-four communications upon the Reptilia and established himself at the age of twenty-one as one of the leading herpetologists of the country.

Even in the papers he presented at this early age he shows keen observation and powers of systematic diagnosis, a wide range of self-acquired knowledge, and familiarity with the personal and scientific characteristics of his distinguished seniors, Agassiz and Leidy. This period included a year's study (1858–59) of anatomy and clinical instruction at the University of Pennsylvania. In 1863 he travelled abroad for several months, visiting especially the museums of Leyden, Vienna, and Berlin, and greatly extending his horizon as a comparative anatomist, for upon his return he at once showed the impulse of a more philosophical spirit, complete familiarity with the history of opinion, and marked power of generalization. Thus his papers, which begin to crowd the pages of the *Proceedings of the Academy of Natural Sciences*, chiefly in recent herpetology and ichthyology, display a new breadth and range as seen in his division of the Anura into the *Arcifera* and *Raniformes* (Firmisternia) and his demonstration of the main evolution principles in these groups.

In 1864 Haverford College called him to a professorship of natural science. This position, however, he held for only three years. Twenty-two years later he again resumed teaching as a Professor of Geology and Paleontology in the University of Pennsylvania, all the interval having been devoted to exploration and research. In 1865 he first began to extend his studies among the Mammalia, especially the Cetacea, recent and extinct, of the Coastal Tertiary. Early in 1866 a wider paleontological field opened in the vertebrata of the Cretaceous marls of New Jersey, whence he procured the remains of Dinosaurs, describing especially the carnivorous *Lælaps*. In the same year appeared the continuation of his tropical American and Sonoran herpetology and his third contribution to the history of the Cetacea. Henceforward his papers become far too numerous to consider together and we must endeavor to follow merely the main outlines of his life-work.

This was a bright era in the history of the Philadelphia Academy; Leidy, Gill, and Harrison Allen being frequent contributors. In 1868 Cope gave his first complete synopsis of the extinct Amphibia of the world. Between 1868 and 1870 he made his first six contributions upon the Plesiosaurs and Mosasaurs of the Cretaceous of Kansas, and in 1871 began his first western explorations in these beds. This led to his appointment as Vertebrate Paleontologist of the U. S. Geological Survey, under Dr. Hayden, and to further explorations in Wyoming (1872) and Colorado (1873), which resulted in the discovery of many new types of fishes, mosasaurs, chelonians, dinosaurs and other reptiles, notably, *Portheus*, *Platecarpus*, *Clidastes*, *Compsemys* (type of the Amphichelydia, Lydekker), *Protostega*, and *Agathaumus*. These were described chiefly in the *Annual Reports of the U. S. Geological Survey* and in the *Proceedings and Transactions of the American Philosophical Society*, and then culminated in his first large volume "*The Vertebrata of the Cretaceous Formations of the West*," No. II, of the Hayden quartos, which was published in 1875.

He spent his summers in the Bad Lands, exploring the Bridger and Washakie, Wasatch, New Mexican, and Judith River (1887) formations. The latter exposures he visited in 1874, in connection with the Wheeler Survey (*Geological Surveys West of the 100th Meridian*) securing a collection which is now preserved in the National Museum, and publishing a most vivid description of the geology of this interesting region. His movements in the field are described by one who was with him as so rapid and full of energy, so regardless of food and rest, that he wore out the other members of his parties and did not allow time for thorough search; yet he himself discovered a number of his most important types.

The fruits of the New Mexican journey appeared in many bulletins and were finally collected in his second great volume, "*The Extinct Vertebrata obtained in New Mexico by Parties of the Expedition of 1874*," Vol. IV., of the Wheeler Survey. In 1874 appeared the first of his studies upon the comparison of American and European horizons, and of his contributions to the John Day fauna. His collections were now accumulating so rapidly as to demand more time for research and for many years he was fortunate in securing the field services of Mr. C. H. Sternberg and especially of Dr. J. L. Wortman. He continued to make brief expeditions, among the last being his trip into the Laramie region.

As early as 1868 it may be said that he had laid the foundations for five great lines of research, which he pursued concurrently to the end of his life; these must, however, be followed separately to be understood and appreciated. Only for comparatively brief intervals would he pursue one line exclusively in order to complete some special memoir, because his marvelous memory apparently held and resumed the details of all the others with perfect ease.

## COMPARATIVE ANATOMY OF THE FISHES.

Cope's work in Ichthyology would alone give him high rank among zoölogists. His friend, Professor Theodore Gill* who has largely contributed to this section of the biography, observed that it was among the Fishes that Cope had rendered his greatest contributions. The same observation, however, has been made by Professor Baur in relation to the Amphibians, and by Scott and Osborn in reference to the fossil Mammalia.

---

* Professor Gill has kindly allowed the writer to use the advance sheets of his memorial address before the American Philosophical Society upon Professor Cope's contributions to Ichthyology and Herpetology.

As early as December, 1861, Cope made what was called a verbal communication to the Academy of Natural Sciences of Philadelphia, in which he noticed several Cyprinoid fishes, two of which he regarded as new, but which were really identical with forms that had been previously described in an imperfect manner. In his early papers (1864) he appears as an enthusiastic systematist, studying especially the living forms of Teleosts, making careful diagnoses of all types that came into his hands, critically considering the problems of distribution, never casting aside those types whose especial difficulties had been the stumbling block of earlier writers. Thus he studied successively the fishes of Michigan (1864-65), of Virginia (1868), of the Lesser Antilles (1870), again the fishes of South Carolina (1871), of Alaska (1872), of Montana, those from South America collected by Professor Orton (1872-78), those from the territories collected by the Wheeler Survey, and even not infrequently new forms from Africa and the East Indies.

Almost from the first Cope ventured upon ground which had been trodden only by the greatest comparative anatomists and ichthyologists, such as Cuvier, Agassiz, Owen, and Günther, and set aside the superficial characters which had been employed in the classification of the fishes. He seems to have been moved by an instinct to seize upon the less conspicuous structures which were none the less of fundamental importance, and to disregard the more conspicuous features, such as the scales, which had formed the chief guide of his predecessors, especially of Agassiz.

A fortunate step in his career was his purchase, while abroad, of Professor Hyrtl's private collection of fish skeletons, which gave him nearly a thousand admirable osteological preparations for immediate study.

A brief glance at history suffices to make clear at what juncture Cope entered this field of science. The term GANOIDES had been originally introduced into zoölogy by Agassiz for all forms having enamel-covered scales, and as applied by him, covered a very heterogeneous combination of fishes totally unrelated to each other. Johannes Müller later retained this name for fishes which were separated from other living forms by a chiasma of the optic nerves, a multi-valvular and muscular conus arteriosus, and an intestinal spiral valve. In this shape the group, Ganoidei, was long accepted as a subclass or order, but in 1866, Owen broke away from the historic regard for external characters, by uniting the Ganoids and Teleosts into the TELEOSTOMI.*

Before the American Philosophical Society, in 1870, and the American Association for the Advancement of Science in 1871, Cope maintained that the primary divisions of the *Teleostomi* are indicated by their fin structure, enunciating a principle which now forms the accepted basis of subordinal classification. *Fin structure* as a taxonomic motive became uppermost in his mind among all the possible keys to the classification of the fishes. It undoubtedly served to direct his attention later to the foot structure of land vertebrates, especially of the great Dinosaurs in 1867 and the hoofed mammals in 1880, as of diagnostic value.

"The evolution of the fins, indeed, and especially of the paired fins, is shown by Cope to be the most satisfactory and philosophical clue to the arrangement of all the minor groups of fishes. Just as the various modifications of the pentadactyl limb in the Ungulate Mammals—the vertebrates which eventually become most completely adapted for progression on land—afford the principal means of determining the natural subdivision of that order; so among the greater groups of fishes—the vertebrates that become specially adapted for progression in water—the successive modifications of the primitive fin-folds form the most obvious clue to the phases through which the various types have passed in the course of their specialzation." (A. Smith Woodward, Catalogue of Fossil Fishes, Pt. II. p. x.)

---

* Fishes having the mouth surrounded by specialized membrane bones as in the Teleosts.

"The most interesting feature of the Crossopterygii consists in the mode of specialization of their fins; and this, as pointed out by Cope, affords a satisfactory basis for the definition of the suborders." (*Ibid*, Pt. II, p. xxi.)

The objections of Kner and others were reinforced by Cope with arguments derived from the osseous parts; and he concluded that it was "evident that the subclass Ganoidea cannot be maintained". He then proceeded to the consideration of the value of other characters and at length resolved to recombine the scattered elements of the great class of Pisces, limited by the exclusion of the Leptocardians and Marsipobranchs, into five primary subdivisions or subclasses.

In these papers he therefore boldly abandons the group of Ganoids and redistributes the fishes into five great subclasses, namely, the *Holocephali* (Bonaparte, 1832-41), *Selachii* (Cuvier, 1817), the *Dipnoi* (Müller), the *Crossopterygii* (Huxley) with paired fins arranged so as to form a fringe around a central lobe, and the *Actinopteryi*. He showed that each of these forms a natural group, and the differentiation between each and its nearest of kin is on the whole well marked. Second to this emphasis upon fin structure was that upon the jaw structure, or the union of the upper jaw with the skull, which separates the *Holocephali* from the *Selachii*. Third, he employs the modifications of the respiratory system for combinations into superfamily groups of the *Physoclysti*, and the number of tail vertebræ for the combinations of *Physostomi*.*

Of these five great divisions he adopted Holocephali from Bonaparte, the Crossopterygii from Huxley, proposing on his own part the Actinopteryi or ray-finned fishes. The latter great subdivision which comprises the majority

---

* "The greatest defect in this system," says Professor Gill, "was Cope's failure to emphasize the important distinction between the cartilaginous fishes (Holocephali and Selachii) with no membraneous skeleton, and the Dipnoi, Crossopteri and Actinopteri, which have a specialized system of membrane bones transmitted with more or less modifications to all the higher Vertebrata."

of living types he broke up into a number of groups by an originality of analysis as marked as in his separation of the five great primary divisions. He first divided the subclass into three groups, named, *Chondrostei*, *Physostomi*; and *Physoclysti* (he subsequently removed the *Chondrostei* from the *Actinopteri*, and applied the name *Malacopteri* to the Physostomes, and *Acanthopteri* to the Physoclysts).

"No less than 24 orders were recognized in the Observations," says Professor Gill,* "to receive the Acanthopterous fishes and these were subsequently added to. Of the 24 orders as many as 15 were endowed with new names. Eight of the names have been adopted by most American naturalists as the designations of orders or suborders. These are *Selachostomi*, *Scyphophori*, *Plectospondyli*, *Haplomi*, *Enchelycephali*, *Colocephali*, *Percesoces* and *Hemibranchii*. The other names have been sunk as synonyms. The most meritorious of Cope's generalizations expressed in ordinal terms, in some respects at least, were those involving the constituents of the order *Plectospondyli* and the separation of the eel-like fishes into different groups.

The order *Plectospondyli* (fishes with the anterior vertebræ coalesced, as distinguished from *Isospondyli* (Cope) in which all the vertebræ are separated) was framed for the numerous fresh-water fishes comprised in the families *Catostomidæ* (Suckers), *Cyprinidæ*, (Carps, etc.,), *Cobitidæ* (Loaches), *Sternopygidæ* (Carapos, etc), and the numerous South American and African fishes representing the Cyprinoideans, constituting the families *Characinidæ* and *Erythrinidæ*. These had been arranged previously in three groups widely separated and superficially quite unlike each other and were considered to be related to forms with which they are now known to have little in common except some external characteristics. Their combination

---

* This section upon the classification of the *Teleostei* is directly quoted from Professor Gill's Memorial Address before the American Philosophical Society as far as the middle of page xvi. A number of minor changes and insertions are made elsewhere in order to make the matter clearer to students.

in one great group or order (by Cope) was a most happy one and even the diagnosis given was good. Nevertheless it was long before the order was recognized by other icthyologists. That it was not recognized earlier was partly due to the inconsistencies in Cope's own presentation, but still more to doubts arising from certain unfortunate complications.

The main characters he assigned to the *Plectospondyli* were the "anterior four vertebræ much modified, and with ossicula auditus," also the presence of a præcoracoid arch. But from this group he differentiated two large orders,[*] distinguished by simple anterior vertebræ, including the form (*Gymnotus*, the electric eel) which had been previously placed in the same family with the *Sternopygidæ*, and which appeared to all other investigators to be at least very nearly related. With many contradictions confronting other workers, it is not strange that they did not at once accept Cope's classification. But his intuition was better than his logic or his application of diagnosis. Time went on. It was ascertained that there was no distinction between the electric eel and the Sternopygids, such as he had alleged; it was ascertained that the opinion (which he shared with distinguished predecessors) that the curious cat-fishes known as Hypophthalmids had "*vertebræ unmodified*" was the extreme reverse of the truth; they were found, in fact, to have the first four vertebræ not only co-ossified but so modified and crowded that they were shoved into the skull and could only be seen when the skull is bisected; the anterior "unmodified vertebræ" of Cope and others being those which succeeded the modified ones.

Thus the objections against Cope's classification were

---

[*] The electric eel was isolated as the representative of a peculiar order (*Glanencheli*) because it was supposed to have "no præcoracoid." Again, the combination of "four vertebræ co-ossified, and with ossicula auditus" was attributed to another order (*Nematognathi*), but within the same order a group was admitted with the attribute of "vertebræ unmodified," although it was remarked that the fishes in question, "the *Hypophthalmidæ*, are indeed scarcely to be referred to this order."

successively dissipated, and the order *Plectospondyli*, modified by the addition to it of his *Glanencheli*, stands out as one of the most important of his system."

All fishes having an eel-like form, continues Professor Gill—that is, with a long, snake-like aspect and without ventral fins—had long been supposed to be nearly related to each other and, if not forming one family (as the older authors believed), to constitute at least a natural series of families. Cope, however, demonstrated that there were great diversities in internal structure among fishes characterized by an external eel-like form. For example, the electric eel and the Sternopygids are not at all related to the typical eels, but really belong to the same great group as the carp, dace, and roach. Although Cope was not the first to recognize this absence of relationship to the eels, he has the unquestioned merit of having first recognized to what others the Sternopygids were to be approximated. Moreover, he segregated the true eels into four ordinal groups, two of which (*Ichthyocephali* and *Holostomi*) are now generally combined in the order *Symbranchia*, while the other two are recognized as suborders of the Linnæan order *Apodes*—an order that is Linnæan, however, only in name and in type.

Professor Gill closes with the following critique:

> "I cannot consider his removal of the 'subclass *Dipnoi*' to a position between the *Holocephali* and his *Elasmobranchii* (*Plagiostomi*,) or his combination of his old subclass *Crossopterygia* with his subclass *Actinopteri* as improvements. But the subdivision of the *Crossoptergyia* into *Rhipidopterygia* and *Crossopterygia* (or what may be rather called *Eucrossopterygia*) and the new orders (or suborders) which he established appear to express morphological details as near as can be done with present material; at least his views, with slight modifications, have been accepted by the best informed living student of the extinct forms—I mean, of course, A. Smith Woodward of the British Museum."

## FOSSIL FISHES.

In 1876 Huxley accepted Cope's separation of the *Holocephali* from the *Selachii*, and these five groups of living fishes stand as the major classification of the present day, which now rests upon the structure of the fins and of the skull, owing chiefly to the labors of Owen, Huxley, and Cope. Cope's interest in the ancestry of the fishes was naturally intensified as he became a more convinced evolutionist, and by his increasing knowledge of the extinct forms. Here his wide preliminary studies among living types stood him in good stead, and stand as a model of the close relations which should always subsist between zoological and paleontological research. He was first brought into contact with extinct fishes among the Cretaceous vertebrate remains from the New Jersey green sand (1869), and continued among the rich yields of the Green River Tertiary whales (1871–77) belonging to the Lower Eocene. Devonias and Carboniferous or older fishes had long been in the hands of Professor Newberry, the pioneer among the students of Palæozoic fishes of North America. Cope's discoveries led him rather among the intermediate types of the Permian period.

In his eager quest of phylogenetic relationships his systematic genius led him always to suggestive and often to permanent results. In fact, the masterly part which Cope has played in the major classification of the fossil, as well as of the recent fishes, may well be gathered from a perusal of the introduction of the three parts already published of the "Catalogue of Fossil Fishes in the British Museum," by Woodward, from which many of the subjoined quotations are taken.

In 1884 he proposed a new subclass of the *Selachii*, namely the *Ichthyotomi*, founded upon the Permian genus *Diplodus*, and subsequently enriched by his discovery of *Didymodus*. Of these Woodward says: "In discussing the bearing of the foregoing facts upon published schemes of classification of the *Elasmobranchii*, the first point to be considered is the validity of Professor Cope's division of the subclass into the two orders *Ichthyotomi* and *Selachii*. If the characters of the dentition are of any systematic importance—and when genera of equivalent age are under comparison we believe they are—there can be no hesitation in associating the European and later Palæozoic Pleuracanths with the skulls of the so-called *Didymodus*, Cope, from the Permian of Texas. (Catalogue, Pt. I., p. xxiii.)

The order *Ichthyotomi* being firmly established in 1889, Cope proposed another great suborder, *Ostracodermi*, to include the peculiar armored fishes without lateral fins, but with jointed appendages apparently articulated with the head plates. Of these Smith Woodward speaks as follows: "A large number of these are still problematical, and it has thus been deemed convenient to treat next in order the great extinct group of Chordate animals to which Professor Cope has applied the name of *Ostracodermi*. These pertain either to the Class Pisces or to some lower denomination yet to be determined. (Catalogue, Pt. II., p. xvii.) The name *Ostracodermi*, is preferred for this subclass, because Professor Cope seems to be the only naturalist who has hitherto ventured to remove the Coccostean fishes far from the order that comprises the *Asterolepidæ*." (Catalogue, Pt. II., p. xviii.)

For the most abstruse problems Cope had an invariable resource of working hypotheses. Thus, the curious fish-like *Bothriolepis* he compared to the armored Ascidian, basing this surprising view upon the remarkable similarity in the arrangement of plates, arguing that it was reasonable to expect in the early period of *Bothriolepis*, that backboned creatures should have been built upon the plan of Ascidian tadpoles.

Cope's final opinions and additions to the arrangement and phylogeny of the fishes appear in this Syllabus, and may be considered as an extension of his earlier work upon the fin and jaw structure. Of this Smith Woodward speaks as follows: "Among the early families, the characters of the median fins lead to the recognition of two or three divisions. It is probable that one type in which the median fin remains undivided and more or less in its primitive condition will eventually be met with, even if it be not already known. This group has received (from Cope) the name of *Haplistia*, and we provisionally assign to it the problematical *Tarrasiidæ*. The second and third types, though now clearly definable, are not satisfactorily formulated in the somewhat fluctuating classifications of Cope; and the terms *Rhipidistia* and *Actinistia* are selected on the present occasion from those already proposed by that author, as being most expressive and accurate." (Catalogue, Pt. II., p. xxii.)

## STUDIES AMONG LIVING AND EXTINCT AMPHIBIANS.

"There never has been a naturalist." writes Dr. Baur, "who has published so many papers upon the taxonomy, morphology and paleontology of the Amphibia and Reptilia as Professor Cope." The first of a series of more than forty papers upon the former group is the one "*On the Primary Divisions of the Salmandridæ, with descriptions of two new species,*" alluded to in his letter above, and presented at the age of 19 (April, 1859). It exhibited the precocious taxonomic instinct which soon afterwards prompted him to attack and rearrange the major divisions of the Amphibia. Rapidly following this first essay by others upon the Anura, in 1865 and 1866 he outlined the larger Ecaudate or Anurous divisions: I. *Aglossa;* II. *Bufoniformia;* III. *Arcifera;* IV. *Raniformia.*

At the age of 25 he described his first extinct Amphibian

*Amphibamus*, from the Carboniferous of Ohio, and at 28 he published his first large quarto memoir, "*Synopsis of the Extinct Batrachia, Reptilia and Aves of North America.*"[*] This contained, in addition to the above, the recent urodelous divisions, *Trachystomata* (*Siren*), *Gymnophidia* (*Cœcilia*), *Proteida* (*Necturus-Proteus*); but of chief importance, to include the Permian and Triassic forms of the world, he proposed the great extinct order *Stegocephali*, which has since been universally adopted. As a supplement to this memoir appeared in 1874 his "*Catalogue of the Air-Breathing Vertebrata from the Coal Measures of Ohio*," including results also published in the Paleontology of the Geological Survey of Ohio of the same year. His researches and collections in the typical coal measures and Permian extended to Iowa and Illinois, leading to the determination of *Cricotus*, which in 1880[†] he made the type of the suborder *Embolomeri*, or *Stegocephalio* with double vertebral rings. In 1877 he received the first remains of *Eryops* and *Trimerorachis*, from the supposed Triassic, but actually Permian, beds of Texas, animals which in 1882 he made the type of the *Rachitomi*, a second suborder of *Stegocephalio*.

This accession of material, as we shall see, ranks with that from the Puerco among the chief events of Cope's scientific career, for the Permian of Texas yielded to him not only these remarkable Batrachians with complex vertebræ, but also the great primitive representatives of the Reptilia. The suborders *Rachitomi* and *Embolomeri* have been grouped as *Temnospondyli* in contrast with the specialized *Labyrinthodontia* and simpler *Microsauria* of Europe, chiefly made known through the labors of Fritsch, Credner, Gaudry, and Miall. Cope's brief memoir of 1884 upon the "*Batrachia of the Permian Period of North America*" summed up his previous contributions, but he anticipated that

---

[*] Trans. Amer. Phil. Soc., read 1868, pub. 1869. See also Proc. Phila. Acad. Nat. Sci., 1868, p. 211.

[†] American Naturalist, p. 610.

the more exhaustive monographic treatment of the rich amphibian and reptilian fauna of this period, exclusively collected and described by him, would constitute a volume of the Hayden Survey memoirs and give him an opportunity of rounding up his prolonged studies. This volume was never completed.

In the meantime his investigations upon the living Batrachia extended to Central and South American species, as well as to include his very original observations upon the laws of geographical distribution of the Amphibia, which were published by the Smithsonian Institution. In 1875 he prepared a "*Check List of the North American Batrachia and Reptilia*" for the U. S. National Museum; this was followed by an essay "*On the Zoological Position of Texas*" (1880). Soon afterwards, at the request of Spencer F. Baird, Secretary of the Smithsonian Institution, he began the preparation of a general work upon the Batrachia; this was facilitated by a manuscript prepared for a work of the same character both by Baird and Girard, but was not completed until 1889. As a volume of 523 pages and numerous plates this work,* while showing many signs of haste and subject to considerable changes in the larger systematic divisions, fortunately remains as a monument of the immense range of knowledge and observation of its author upon the structure and habits of the living representatives of this group. It must always be a matter of regret that he could not have published his final views upon the extinct forms. One of his most important generalizations from the latter, contained in a short memoir, "*The Intercentrum of the Terrestrial Vertebrata*" (1881), is that the vertebræ of living amphibia are composed of intercentra and are, therefore, not homologous with the true centra (pleurocentra) of reptiles, birds, and mammals.

---

* "The Batrachia of North America." Bull. No. 34, U. S. Nat. Museum.

## CLASSIFICATION OF THE REPTILIA BY CHARACTERS OF THE FEET AND CRANIAL ARCHES.

We have already traced Cope's initial work upon the Reptilia. As in other groups, his researches rapidly branched out in many directions, first, his treatment of the reptiles of the Bridger and other fresh-water Tertiary lakes in connection with the mammalian fauna; second, the continuation of his systematic description of the Kansas Cretaceous fauna; third, his brief papers upon the herbivorous Dinosaurs of the Dakota (1877 and 1878) and the horned Dinosaurs (*Monoclonius*) of the Laramie formations; fourth, his numerous papers upon the Reptilia of the Triassic and especially of the Permian.

The latter discoveries must be considered the most important and unique in their influence upon paleontology. In 1875 he first announced the existence of reptiles in the American Permian, and in 1877 he reported the first primitive *Crocodilia* (*Belodon*) and *Dinosauri* (*Clepsysaurus* and *Zatomus*) in the Triassic of North Carolina.

The detailed sequence of this reptilian work is clearly stated by Professor Baur. Already in 1864 he published a paper on the characters of the higher groups of the *Squamata,*[*] a group proposed by Oppel to include the lizards and snakes. Two years later he made his first remarks about the Dinosaur *Lælaps,*[†] and in 1867 he compared the carnivorous Dinosaurs with the birds.[‡]

> "Prof. Cope gave an account of the extinct reptiles which approached the birds. He said that this approximation appeared to be at two points. The first by the *Pterosauria,* to which the modified bird *Archæopteryx* presented points of affinity. The second, and one not less striking, is by the *Dinosauria* of the orders *Gonio-*

---

[*] Proc. Acad. Phila., 1864, p. 224.

[†] *Lælaps aquilunguis*, Cope. Proc. Acad. Nat. Sci., Phila., July, 1866, pp. 275-279.

[‡] Ibid., 1867, pp. 231-235.

*poda* and *Symphypoda*. He showed the essential differences between the ordinary *Dinosauria* and the birds to consist in the distinct tarsal bones in two series, the anteriorly directed pubes, and the presence of teeth, of the first class. In the genus *Lælaps*, Cope, type of the *Goniopoda*, the proximal series of tarsal bones was principally represented by one large astragaloid piece which had a very extensive motion on those of the second series. This was immovably bound to, and embraced, the tibia, and was perhaps continuous with the fibula, much resembling the structure of the foot of the chick of the ninth day, as given by Gegenbaur. The zygomatic arch was of a very light description. He was convinced that the most bird-like of the tracks of the Connecticut sandstone were made by a nearly allied genus, the *Bathygnathus*, Leidy. These creatures, no doubt, assumed a more or less erect position, and the weight of the viscera, etc., was supported by the slender and dense pubic bones, which were, to some extent, analogous to the marsupial bones of implacental Mammalia, though probably not homologous with them.

He said he was satisfied that the so-called clavicles of *Iguanodon* and other *Dinasauria* were pubes, having a position similar to those of the *Crocodilia*.

Also, that a species of *Lælaps* had been observed in France, by Cuvier, which was different from the *Lælaps aquilunguis*, and which he proposed should be called *Lælaps gallicus*.

*Compsognathus*, Wagner, type of the *Symphypoda*, expressed the characters of the latter in the entire union of the tibia and fibula with the first series of tarsal bones, a feature formerly supposed to belong to the class Aves alone, until pointed out by Gegenbaur. This genus also offered an approach to the birds in the transverse direction of the pubes (unless this be due to distortion in the specimen figured by Wagner), their position being intermediate between the position in most reptiles and in birds. Other bird-like features were the great number and elongation of the vertebræ of the neck, and the very light construction of the arches and other bones of the head.

He thought the penguin, with its separated metatarsals, formed an approach on the side of the birds, but whether the closest approximation to the *Symphypoda* should be looked for here or among the long-tailed *Ratitæ* (ostrich, etc.), he was unable to indicate." (Proc. Acad. Nat. Sci., Philadelphia, Vol. XIX, 1867, pp. 234–5.)

Huxley's paper upon the same subject appeared in 1868.*
In 1870 Cope read an important paper before the American Association "*On the homologies of some of the Cranial Bones of the Reptilia and the systematic arrangement of the class.*"† He discussed the following topics: 1. Homologies and Composition of the cranial arches. 2. The cranium of the Ichthyosauria. 3. The cranium of the Anomodontia. 4. The homologies of the opisthotic. 5. The squamosal bone. 6. The columella (epipterygoid). 7. The systematic arrangement of the Reptilia. 8. Critical remarks on the system. 9. The Rhynchocephalia and supposed Lacertilia of the Trias and Permian. 10. Stratigraphic relation of the orders of Reptilia.

His classification is as follows:

A. Extremities beyond proximal segment not differentiated as to form.

    I. *Ichthyopterygia:* Order *Ichthyopterygia.*

B. Extremities differentiated.

    II. *Streptostylica:* Orders *Lacertilia, Pythonomorpha, Ophidia.*

    III. *Synaptosauria:* Orders *Rhynchocephalia, Testudinata, Sauropterygia.*

    IV. *Archosauria:* Orders *Anomodontia, Dinosauria, Crocodilia, Ornithosauria.*

In 1875 the large volume "*The Vertebrata of the Cretaceous Formations of the West*" appeared, as Vol. II of the Rep. U. S. Geol. Surv. Territ. (302 pp., Pl. LVII.). This work contains extensive descriptions, especially of the

---

*Popular Science Review, 1868, pp. 237-247.

†Proc. Assoc. Adv. Sci., XIX, pp. 194-247.

Mosasaurs, also of Testudines, Crocodilia, Plesiosaurs and Dinosaurs (Iguanodontia): *Agathaumas*, Cope (*Triceratops*, Marsh); *Hadrosaurus*, Leidy; (*Trachodon*, Leidy; *Diclonius*, Cope, *Laosaurus*, Marsh).

Cope's most epoch-making contributions, however, are his researches on the Permian Reptiles of Texas, which commenced in 1878. In the *Proceedings af the American Philosophical Society* of this year he established the sub-order *Pelycosauria* of the *Rhynchocephalia* to contain *Clepsydrops*, *Dimetrodon*, *Diadectes*, *Bolosaurus*, *Pariotichus*, *Empedias*. In the December *American Naturalist* of the same year the order *Theromorpha* (reptiles having characters of mammals) was created, with the sub-orders *Anomodontia*, Owen, and *Pelycosauria*, Cope. The *Pelycosauria* were considered as the ancestors of the *Mammalia*. In 1880* a new division of the *Theromorpha* was established, with the name of *Cotylosauria*, to contain the family *Diadectidæ*. In a skull of *Empedias* he described two occipital condyles, being misled by the missing basioccipital. In 1883† he placed his genera *Pariotichus* and *Pantylus* in a new family, *Pariotichidæ*, characterized by the over-roofing of the temporal fossæ and the presence of the supra-occipital and par-occipital plates (intercalare, Cope). He now found the basioccipital in position and the order *Cotylosauria* was given up. In 1890 (March 12th), Cope, however, again employed the *Cotylosauria* as a suborder under the *Theromora* distinguishing three families: *Careiasauridæ*, *Pariotichidæ*, *Diadectidæ*. In 1882‡ Seeley had established the order *Pareiasauria*, which Lydekker (1889) and Zittel considered as a suborder of the *Theromora*. In 1892§ the *Cotylosauria* was raised to ordinal rank by Cope.

The last two papers published by Cope in the *Proceed-*

---

*American Naturalist, p. 304.

†Proc. Amer. Philos. Soc., p. 631.

‡Proc. Roy. Soc., Vol. 44, p. 383.

§Trans. Am. Phil. Soc., Vol. XVII.

*ings of the American Philosophical Society* give much new evidence about this very interesting group. The titles of these papers are: "*The Reptilian Order Cotylosauria*"* and *Second Contribution to the History of the Cotylosauria.*"† In this paper a new family, *Otocœlidæ,* was described with the following characters: Posterior border of temporal roof excavated laterally by the meatus auditorius externus. Teeth present in a single row, not transversely expanded. Ribs immediately overlaid by parallel transverse derm-ossifications which form a carapace. This family he considered, or at least suggested was, ancestral to the *Chelonia.*

Cope had in preparation for many years an extensive work on the *Lacertilia* and *Ophidia* of the United States, to be published, like his *Batrachia,* in a bulletin of the United States National Museum.‡ The MSS. for this work cost him much labor, especially during the last two years of his life and for a while interrupted all his other work. It was characteristic of him to turn aside for a laborious detailed investigation upon the soft anatomy of the snakes in the hopes of finding some satisfactory means of classifying this puzzling group from the structure of the copulatory organs. This investigation constituted his latest original work and was barely completed before his death.

### EVOLUTION AND CLASSIFICATION OF THE MAMMALIA.

Up to 1868 Leidy held the Western paleontological field exclusively. In this year Marsh and Cope also entered the

---

*Proc. Am. Philos. Soc., Vol. XXXIV, 1896 (Feb. 2d), pp. 436–457, Pls. VII-X.

†Ibid., Vol. XXXV, pp. 112-139, Pls. VII-X, Aug. 15, 1896.

‡Many preliminary papers have appeared for this publication, of which the following are named:

"An analytical Table of the Genera of Snakes." Proc. Am. Philos. Soc., 1886, pp, 479-499

"The Osteology of the Lacertilia." Proc. Am. Philos. Soc., Vol. XXX, 1892, pp. 185–221, Pls. II-VI.

"On Degenerate Types of Scapular and Pelvic Arches in the Lacertilia." Journ. Morphol., Vol. VII, 1892, pp. 223-244, Pl. XIII.

"The Classification of the Ophidia." Trans. Amer. Philos. Soc., Vol. XVIII. April 15, 1895, pp. 186–219, Pls. XIV-XXXIII.

"On the Hemipenes of the Sauria." Proc. Acad. Nat. Sci., Phil., August. 1896, pp. 461–467.

Western territory and began the simultaneous exploration and description of a limited fauna in a somewhat limited region, with the inevitable result of a struggle for priority and a permanent rupture of friendly intercourse. It is necessary to allude to the fact, because it greatly affected the subsequent history of American paleontology. Fortunately, the western fossil area proved to be a vast one, and the remarkable discoveries by Wortman in the Big Horn and Wasatch, beginning in 1878, also by Baldwin in the Puerco of New Mexico, beginning in 1880, and the explorations already described of Cummins in the Permian of Texas, afforded Cope a noble field of research quite free from the haste of rivalry.

As early as 1864 Cope had outlined a classification of the *Squamata,* taking advantage of characters distinguishing the snakes and lizards given by Müller, also those given by Stannius. Here, as in the fishes, Cope perceived the superior value of the hard parts of the body to the tongue and soft parts, which were then employed by the greater number of anatomists; as well pointed out by Boulenger:

> "Whilst engaged in a revision of the Lizard-collection in the British Museum, I have felt the necessity of a thorough systematic rearrangement of the order *Lacertilia.* The classifications proposed by Dumeril and Bibron and Gray, and now still generally in use, with slight modifications, are, on the whole, as unnatural as can be, and founded, to a great extent, on characters of pholidosis and physiognomy. Physiognomy is worth nothing as a guide in the formation of higher groups; as to the characters afforded by the scales I have convinced myself that they are very deceptive, and ought to be taken into consideration in the definition of families only when accompanied by other characters. Like Cope, whose lizard families I regard as the most natural hitherto proposed, I shall lay greater stress on osteological characters and on the structure of the tongue. Special importance must also be attached to the presence or absence, and the structure, of dermal ossifications on the head and body, and these

will be found to correspond with many other characters. Bocourt, to whom is due the merit of having pointed out their systematic importance, did not realize the very great progress made by means of that character, the modifications of which he so ably illustrated, for he still maintains the artificial group Scincoidiens, in spite of the objections of Cope, whose views are evidently confirmed by the researches of the French herpetologist." ("Synopsis of the families of existing Lacertilia." Annals and Magazine of Natural History, Vol. XIV, Fifth Ser., 1884.)

## EVOLUTION OF THE MAMMALS.

Cope's most numerous and voluminous writings were devoted to Mammals, and to appreciate the importance of his contributions to this group it is necessary to cast a brief glance over the history of mammalian paleontology. Cuvier, the founder of this branch of science, had represented the *ecole des faits* in opposition to Geoffroy St. Hilaire, and founded a school wholly opposed to generalization as to the origin and succession of animal life, and firmly adherent to the Special Creation hypothesis. As a master of comparative anatomy, Cuvier exerted an immense influence upon the succeeding French paleontologists, such as Jourdan, Croizet, Cristol, De Blainville, Aymard, Lartet, and Pomel. It is true that De Blainville and Gervais showed a wide range of knowledge, but Gaudry was the first of the French paleontologists to grasp the spirit of evolution. In Germany, Jäger and Blumenbach ranked as more or less voluminous descriptive writers, while Kaup showed superior powers of analysis.

Cuvier's unnatural classification of the hoofed animals into the Solipédes, or horses, and Pachyderms, or rhinoceroses and hippopotami, prevailed and was adopted even by Leidy in this country. Richard Owen, by far the greatest man after Cuvier, made a decided advance, and, as in the classification of the fishes and reptiles, was the direct predecessor of Cope. He defined the new mammalian orders, *Marsupialia* and *Toxodontia*, but he especially broke down Cuvier's classification of the Ungulates by distinguishing the *Perissodactyla* from the *Artiodactyla* upon the basis of foot structure, the importance of which Cuvier himself had only dimly perceived.

In this country the earlier contributions of Jefferson, Harlan, and Gibbes were overshadowed in the mid-century by the numerous valuable works of Leidy, who became at once the founder of American Vertebrate Palæontology, although he entirely lacked the philosophical spirit either in anatomy or in evolution. Thus, from all this long post-Cuvierian period an immense number of facts issued, but only two generalizations, the first of what may be regarded as the great laws or principles in the evolution and classification of the Mammalia. These laws are as follows:

I.—*The Law of Brain-Growth.*—This principle, that the older Mammalia had smaller brains, and that in order of succession there was a steady increase in brain size, was enunciated by Lartet, and has been subsequently elaborated and demonstrated by Marsh.

II.—*The Classification of the Hoofed Animals by Foot Structure.*—This was discovered by Owen in his division above alluded to, which first directed attention to the importance of differences in the feet.

The three vertebrate paleontologists of the new period who responded most fully to the Darwinian movement were Huxley, who unwillingly entered the field, but soon found an opportunity of overthrowing Cuvier's Law of Correlation. Huxley's greatest, generalization was the central position of the order *Insectivora.* He had few opportunities of working upon fossil mammals. He erroneously placed *Paloplotherium* instead of *Hyracotherium* in the horse line, and erroneously supported Reichert's theory of the homology of the quadrate. Cope and Marsh alike responded to the Darwinian impulse. In Russia appeared Waldemar Kowalevsky, who had a short but brilliant career in Mammalian Palæontology. He announced the third great principle:

III.—*Law of Adaptation of Foot Structure in Ungulates by Reduction, Accompanied by Shifting of the Metapodials.*—Kowalevsky's ancestral type of ungulate or Protungulate, like that of Huxley, was believed to possess five digits·

In the mean time the gifted John A. Ryder, of Philadelphia, was attacking the mechanical evolution of the feet and teeth.

Cope, who had practically entered Mammalian Paleontology in 1870, found a great field of facts lying fallow before him, with the three above principles as a means of interpretation. Keen to wed philosophy with anatomy, in 1873 he added to the generalizations of Huxley and Kowalevsky the additional principle:

IV.—*The Ancestors of the Hoofed Animals possessed Bunodont or Hillock-like Teeth.*—This prophecy was speedily verified by Wortman's discovery of *Phenacodus.* This discovery led Cope on to a re-classification of the entire group of Ungulates by foot structure—the logical outcome of the movement in which Owen, Kowalevsky, Huxley, Ryder, and himself had participated. This centered about the following principle:

V.—*The Law of Taxeopody. That the primitive feet of Hoofed Animals were Plantigrade, like those of the bear, with serial unbroken joints.*—Thus he proposed in the early eighties the four new Orders, two of which have been permanently adopted into Paleontology:

| Cope. | Marsh. |
|---|---|
| *Taxeopoda.* | *Protungulata.* |
| *Amblypoda.* | *Amblydactyla.* |
| *Condylarthra.* | *Holodactyla.* |
| *Diplarthra.* | *Clinodactyla.* |

Kowalevsky, in 1873, had pointed out the significant articulations of the metapodials; Cope here showed the still greater importance of the mutual articulations of the podials, firmly establishing thereupon the orders *Condylarthra* and *Amblypoda*, uniting Owen's Perissodactyla and Artiodactyla into the *Diplarthra*, and by hypothetical phyla connecting the Proboscidia and Hyracoidea with a still-to-be-discovered plantigrade, bunodont stem, the "protungulate" of Huxley and Kowalevsky. These generalizations, despite errors of excess and of detail which Rütimeyer and Osborn have pointed out, constituted the first distinct advance in mammalian classification since Owen demolished Cuvier's "pachydermata;" they rank with Huxley's best work among similar problems, and afford a basis for the phylogenetic arrangement of the hoofed orders which has been adopted by all American and foreign paleontologists. Having thus raised the feet, a region of the body so long neglected by the followers of Cuvier (with the exceptions noted), to a position of prime importance in classification, it was his good fortune to discover in the collections from the Puerco or Basal Eocene the following law:

VI.—*Law of Trituberculy. That all Types of Molar Teeth in Mammals originate in Modifications of the Tritubercular Form.*— It became apparent that the hoofed mammals had sprung from clawed ancestors, but the Wasatch period was too remote from the parting to furnish conclusive evidence. This evidence came in a flood from the underlying Puerco fauna, the systematic treatment of which constitutes the most unique section of Cope's work among the extinct mammalia. From this material originated the above great generalization—namely, that the primitive pattern of the molar tooth consists of three tubercles. Around this *trituberculy* centers the whole modern morphology of the teeth of the mammalia and the establishment of a series of homologies in the teeth of most diverse types, wholly unsuspected in the "Odontologies" of Cuvier and Owen, connecting the most ancient Mesozoic mammals with the most modern and specialized types, and applying even in the teeth of man. The force and application of the tritubercular law Cope clearly perceived, but left to others fully to work out and demonstrate. It promises ultimately to give us the key to the entire phylogeny of the mammalia, extending to every division of the Marsupialia and Placentalia, and will probably be found among the Monotremata.

Thus the final philosophical working basis for the evolution of the hoofed, as well as the clawed, animals has been gradually established, for, as Professor Marsh observes in his monograph on the Dinocerata, "the characters of most importance in the evolution of the Ungulates are the teeth, the brain and the feet."

It now only remained for Cope to take another step beyond Huxley and Kowalevsky, and, aided by fortunate discoveries in the field, he demonstrated that the ancestors of the hoofed animals were clawed animals, establishing the Seventh Law:

VII.—*The Hoofed Orders Converge towards the Clawed types of Creodonta and Insectivora.*

So much for the great generalizations which establish Cope historical position in Mammalian Paleontology. These are the mountain peaks, the points where exploration and discovery were followed by happy inspiration in a chain of contributions which includes his exposition of the faunal succession of the Mammals from the base to the summit of the Tertiary, as well as two or three discoveries of great interest in Cretaceous. His most conspicuous work relates to the Puerco, with its extremely primitive hoofed and clawed animals and primates. Here he established the existence in this country of the *Plagiaulacidæ* and defined the order *Multituberculata.* That from the Wasatch is perhaps next in value, and in succession rank his contributions from the John Day, Loup Fork, Blanco, Palo Duro and Port Kennedy Bone Cave.

As an explorer he had marked success, finding the unique skeleton of *Hyrachyus*, of *Loxolophodon*, a name which was telegraphed to the American Philosophical Society, and converted by the operator into *Lefalophodon*. In the Bridger, Cope himself found the lower jaw of *Anaptomorphus*, a little monkey with a dental formula like that of man, which, owing to its extreme antiquity, occasioned him a greater surprise than any discovery he ever made. He also found the last of the great race of Uintatheres at the top of Washakie Mountain of Central Wyoming. We owe to him alone our knowledge of the scanty Wind River fauna. From the White River Oligocene his materials were poor and his work less satisfactory. From the rich Upper Oligocene, with the assistance of Wortman, he secured fine collections and has especially enriched our knowledge of the *Anchitheriidæ*, *Felidæ* and *Canidæ*. From the Upper Miocene Deep River and Loup Fork beds he has practically contributed all that we know, especially of the Rhinoceroses, Horses, Mastodons, Camels, and other ruminants and carnivora. Of the latter fauna his most complete papers were upon the evolution of the *Oreodontidæ*. His latest contributions to our knowledge of the fossil Mammalia were upon the fauna of the Blanco and Palo Duro, or Goodnight beds of Texas, and the rich cave fauna from Port Kennedy, Pa., brought together by his warm friend, Dr. H. C. Mercer. It was his intention to cover the entire later Tertiary in a second part of the "Tertiary Vertebrata;" many of the plates and much of the MSS. of which volume are ready.

The "*Tertiary Vertebrata*," Vol. III., of the Hayden quartos, published in 1883, is his most imposing contribution to paleontology, including his studies of all the vertebrate fauna of the Tertiary lakes west of the Rockies. This work of over a thousand pages and eighty plates is said to have been the despair of the public printer, owing to the constant additions made while in press. It extends from the Puerco to a portion of the Lower Miocene fauna. Besides the full description and illustration of the great hoofed orders above alluded to, it contains the full exposition of the characteristic forms of *Creodonta,* an order of primitive carnivora, which, as we have seen, he separated from the Marsupialia in 1875, and in which he placed six families of mammals from different parts of the world.

Before leaving the mammals it is fitting to speak of his work upon "kinetogenesis," or the mechanical origin of the hard parts of the body, especially of the teeth, vertebræ, and limbs. An invaluable paper by his friend and later colleague, Ryder, put him upon this line of investigation, the results of which he published in a long series of papers, culminating in his memoir upon the "*Origin of the Hard Parts of the Mammalia,*" and in his collections of essays in the "*Origin of the Fittest*" and "*Primary Factors of Organic Evolution.*" One of his chief motives in these researches was the demonstration, which he believed they afforded, of the hereditary transmission of the effects of individual efforts, use, and disuse; even if this motive is subsequently shown to be an illusive one, by our future knowledge of the real nature of evolution, these investigations lose little, if any, of their intrinsic value. First, as in all his work, he brings together an immense array of valuable facts and observations; second, he extends the principle of the independent origin of similar structures; third, he in most cases, successfully establishes the actual mechanical adaptive or teleological relations of the parts described; fourth, he traces the course of phylogenic modification in a number of important organs and thus establishes certain obscure homologies, notably those in the teeth of *Amblypoda,, Coryphodon* and *Uintatherium.*

As to his scientific character apart from his genius, which is indefinable, we signalize his appreciation of the most significant or diagnostic character in a group. Among his fellow workers in the same field, whether upon the fishes, amphibians, or mammals, he was quick to comprehend and seize upon a strategic position. While others were plodding on serenely in the description of facts, giving all an equal value, Cope, with an eagle eye, would sweep down upon some great distinctive fact and point out its supreme importance. Thus he projected the *Creodonta* out of numerous forms, such as *Palæonictis*, *Hyænodon*, *Arctocyon*, which had been discovered and studied for many years in France. It is to be regretted that he did not more willingly surrender some of his own hypotheses. He clung to his erroneous mechanical explanation of the origin of Ungulate foot structure long after it had been disproved by the present writer. Like all of us, perhaps, he loved his own hypotheses, and once observed in jest in regard to a fossil which opposed one of his theories, "I wish you would throw that bone out of the window."

He was no respecter of authority *per se*. Even if sometimes mistaken his fearless criticisms were chiefly animated by high ideals and readiness to change the existing order of things. He was full of cheer and determination when things looked most unpromising, allowing nothing to disturb the composure which is so essential to research. His life, in fact, became a fine illustration of the happiness attendant upon plain living and high investigation which he foresaw at the early age of nineteen.

---

In this introduction the writer has drawn freely upon a biography published in *Science*, also upon valuable materials which have been furnished by Professor Theodore Gill, Cope's lifelong friend, and by Professors Baur and Dean. Professor Gill has revised the proofs relating to Fishes; those relating to Mammals have been revised by the writer. General editorial revision has been made by Dr. J. Percy Moore.

# Syllabus of Lectures
ON THE
# VERTEBRATA

# CONTENTS.

# PREFACE.

The present book is a corrected and extended edition of The Syllabus of Lectures on Geology and Paleontology; Part III, Paleontology of the Vertebrata, published July 8, 1891. It was originally designed for use in the Extension Lectures of the University of Pennsylvania, and I have used it as a text-book for the undergraduate classes in the School of Biology of the University. The system adopted is, with some minor exceptions, that which was first presented by the author in the American Naturalist of October, 1889. This was based upon original research on the recent and extinct forms, with the exception of the part relating to the Aves. This was taken, with little modification, from Stejneger.

E. D. COPE.

*University of Pennsylvania,*
*Philadelphia, 1897.*

# INTRODUCTION.

In the following pages the attempt is made to bring together the information which we possess as to the characters of the divisions of the Vertebrata above families which are available for the determination of their relations by the paleontologist. These characters, which are of necessity those of the hard parts, must be of the first importance to the discovery of the phylogenies, since the soft parts are unavailable. It is, however, true that the relations of these are close enough to render our inferences from the former generally safe. Fortunately, also, the living remnants of extinct groups are sufficiently numerous to enable us to check our studies of the osteology. Thus we have the Branchiostoma, the lampreys, the Ceratodus and Lepidosiren, the Sphenodon, and the Monotremata, to which to refer when we desire to learn approximately the characters of the soft anatomy of ancient forms.

All of the characters of the various divisions are not given. In fact, when all extinct forms come to be known, no division is likely to be defined by more than one character. At present several characters may be often ascribed to various divisions, but one of these will ultimately prove to be the essential one. It is the object of the present synopsis to bring these definite characters into prominence; hence they are always stated first. The method of keys is adopted as the most perspicuous method of exhibiting them.

We are embarrassed in the endeavor to present the relations of the earliest and the lowest Vertebrata by a want of knowledge of their structure, and by the absence from our collection of numerous intermediate forms which must have existed. Until our knowledge is more complete, the arrangement, especially of the contents of the class Agnatha, must be regarded as largely provisional.

The ossification of the skeleton of the Vertebrata has developed first on the exterior of the head and body and in the sheath of the chorda dorsalis, and has then penetrated inwards. The limbs have preceded in time the arches (scapular and pelvic) to which they are, in the higher forms, attached. Hence we find in such genera as Cephalaspis and Bothriolepis pectoral limbs without a scapular arch, but with merely dermal ossifications to which they are attached. This is parallel to the general absence of most of the pelvic arch in fishes. The limbs themselves are supposed to be radial ossifications in primitive longitudinal folds of the body integument, some of which remain in large part, as the dorsal fin of various fishes; while more frequently but few of the radii remain, as in the limbs of most Vertebrata. (Fig. 1.)

The use of this syllabus presupposes a knowledge of the rudiments of vertebrate anatomy. The subject is presented in zoological order, but tables are given, in which the taxonomic divisions are represented in their stratigraphic position and succession.

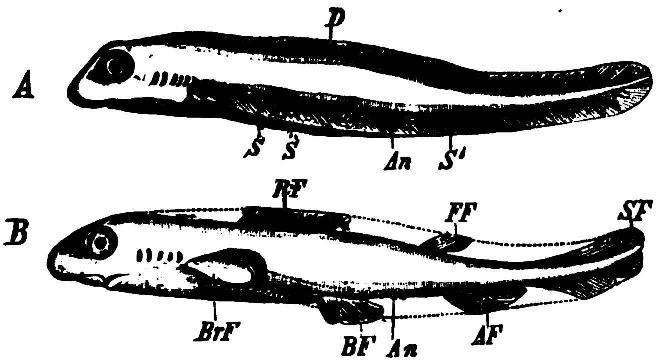


FIG. 1.—Diagrammatic representation of primitive and derivative types of lateral and median fins. *A*, primitive condition, fins continuous; *B*, derivative condition, fins distinct and specialized. *D*, dorsal fin; *BrF*, pectoral; *BF*, ventral; *AF*, anal; *SF*, caudal; *RF*, dorsal; *FF*, second dorsal fin. From Wiedersheim.

The branch Vertebrata* is divided into the following superclasses:

| | |
|---|---|
| No skull nor skeleton; notochord short, anterior; nervous center a longitudinal cord; | *Hemichorda.* |
| No skull nor skeleton; notochord caudal only; nervous center a ganglion; | *Urochorda.* |
| No skull; notochord extending throughout the body, included in a membranous sheath, as is the cord-like nervous axis above it; | *Cephalochorda.* |
| A cartilaginous or bony skull and skeleton, which extends throughout the body; central nervous system a longitudinal cord terminating in a brain within the skull; | *Craniata.* |

## Superclass I.—HEMICHORDA.

There is but one class of Hemichorda:

| | |
|---|---|
| Not metameric; no atrium; | *Helminthophya.* |

### Class I.—HELMINTHOPHYA.

Two orders of this class are known which differ as follows:

---

* The Vertebrata (or Chordata) as now extended, may be defined as cœlomate Metazoa, possessing a longitudinal, axial, cellular supporting rod (the notochord), derived from the hypoblast (except Hemichorda ?) and in the mesoblastic sheaths of which the vertebral centra form in the higher types; with the walls of the pharynx perforated by openings (gill slits, visceral clefts, stigmatæ), placing its lumen in communication with the exterior; with an epiblastic central nervous system which is in whole or in part tubular, which lies dorsal to the notochord and which is not perforated by the functional mouth; and with the mesoblast segmented (obscurely in Urochorda). In the different groups any of these characters may be persistent, or temporary and embryonic, or adaptively modified and obscure.—ED.

Respiration pharyngeal; no external branchiæ; alimentary canal straight, traversing the body lengthwise; *Enteropneusta.*

Respiration wholly or in part performed by external branching processes; alimentary canal bent upon itself, anus at oral extremity; *Lophopneusta.*

The order of ENTEROPNEUSTA includes but one family, the Balanoglossidæ, which consists of animals of wormlike form, which burrow in the soil of the seacoasts of most continents between high and low tide. They have a larva resembling that of the Echinoderma.

The order of LOPHOPNEUSTA includes sessile, and so far as yet known, compound forms, which inhabit the ocean bed, attached to solid substances. There are two families, the Cephalodiscidæ with gill-slits, and the Rhabdopleuridæ in which gill-slits are wanting.

No extinct forms of Helminthophya are known.

## Superclass II.—UROCHORDA.

There is but one class of Urochorda:

Not metameric; a mantle covering the body; respiration pharyngeal; heart distinct, saccular; *Tunicata.*

### Class I.—TUNICATA.

There are three orders of Tunicata as follows:

Cloaca posterior; caudal appendage persistent. Individuals simple, free; *Perennichordata.*

Cloaca posterior; caudal appendage absent or caducous; protostigmata undivided; mostly pelagic; *Thaliacea.*

Cloaca dorsal; caudal appendage caducous; protostigmata divided into rows of secondary stigmata; mostly fixed; *Ascidiæ.*

The Tunicata have sac-like bodies, and are marine in habitat. Some of the Tunicata are free-swimming, and these may consist of single or conjoined individuals. Others are attached, some by a peduncle and others sessile, separately or in colonies. No extinct species of Urochorda are known. The Thaliacea and Ascidiæ are degenerates from the vertebrate line. The families are:

PERENNICHORDATA: Appendiculariidæ.

THALIACEA: Salpidæ, Pyrosomidæ.

ASCIDIÆ: Botryllidæ; Ascidiidæ; Clavellinidæ.

## Superclass III.—CEPHALOCHORDA.

The only class of the Cephalochorda is the following:

Walls of the body muscular myotomes; no jaws nor extremities; pharyngeal walls fissured; heart a longitudinal vessel, which gives off branchial vessels which unite into an aorta; a liver and vena cava present; *Acrania.*

### Class I.—ACRANIA.

Of this class but one order is yet known:

Pharyngeal fissures enclosed externally by a fold of the integument, which encloses a chamber (atrium) which opens inferiorly; openings of alimentary canal at opposite extremities; heart tubular; *Leptocardii.*

The species of the only family, the Branchiostomidæ (the lancelets), are of compressed, worm-like form, and burrow in the soil of the shores of all oceans. No fossil remains of them have been yet found.

## Superclass IV.—CRANIATA.

The five classes of the Craniata are defined as follows:

I. No lower jaw nor pectoral arch.

Internal skeleton not ossified; *Agnatha.*

II. Lower jaw and pectoral arch present.

A, Basicranial axis not ossified, supported by a parasphenoid bone; vertebral column consisting chiefly of intercentra; ribs myotomic; ANAMNIA.

Limbs represented by many-radiate fins, which are also present on the median lines of the body; a coracoid bone; heart with two chambers; one or no occipital condyle; no internal nares; *Pisces.*

Limbs consisting of one basal element, two propodials, and metapodials and digits; no median fins; lower jaw attached to a suspensorium, complex; no opercular bones; a coracoid; heart with three chambers; two occipital condyles; internal nares; *Batrachia.*

AA, Basicranial axis ossified; no parasphenoid;

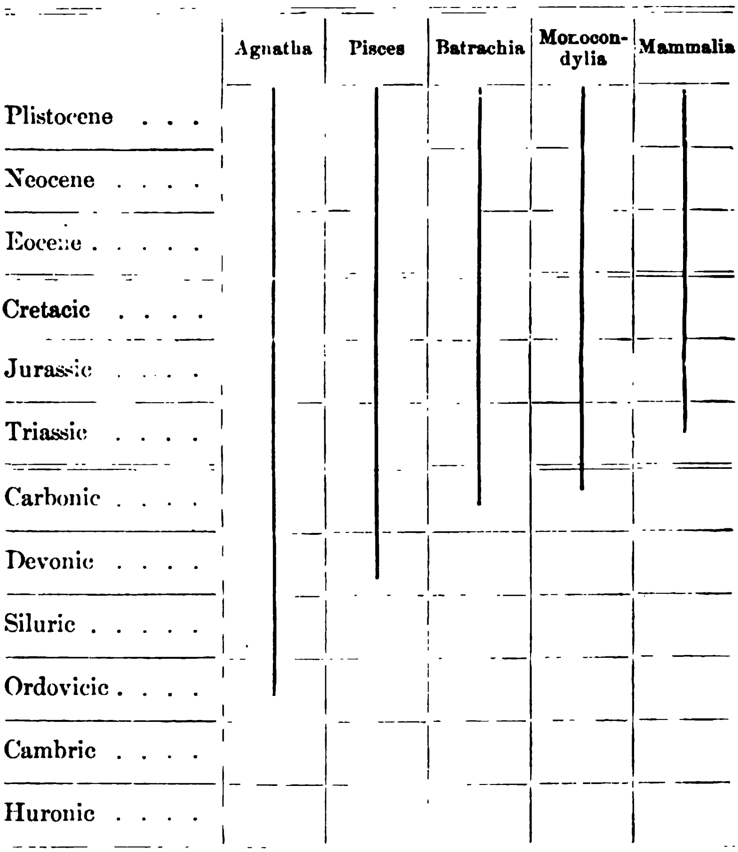
ribs intermyotomic; vertebral column consisting chiefly of centra; an amnion and allantois; AMNIOTA.

Limbs as in Batrachia; one occipital condyle; a suspensorium of the lower jaw; mandible segmented; a coracoid bone; ankles between first and second rows of carpal and tarsal bones; heart with three or four chambers; *Monocondylia.*

Limbs as in Batrachia; two occipital condyles; no suspensorium of the lower jaw; mandible not segmented; coracoid generally not distinct; ankles between propodial bones and carpus or tarsus; heart with four chambers; *Mammalia.*

The period of appearance and duration of each of these classes is exhibited in the accompanying table. It will be observed that the order of appearance corresponds with the natural order of structural complexity, the simplest appearing earliest and the most complex last. It must be mentioned that it is probable that each of the classes appeared a little earlier than the time assigned them in this table. The discovery of the fossil remains is regarded as the first positive indication of the presence of a species of a given class. Spines uncertainly referred to sharks (Pisces) have been found in the Middle and Lower Siluric in Europe and North America respectively. Foot impressions, probably of Batrachia, have been found in the Carbonic at lower horizons than the bones. Tracks, probably of birds, have been found in the Trias. A fore limb, probably of a mammal, has been found in the Permo-Triassic Karoo formation of South Africa.

The geological range of these classes is as follows:



## Class I.—AGNATHA.

The known members of the class Agnatha are a very small representation of those that once existed; and they present a great variety of characters, having little affinity with each other. Three subclasses are most distinctly indicated:

| | |
|---|---|
| An osseous dermal skeleton with lateral limb-like appendages; | *Ostracophori*. |
| An osseous axial skeleton; no dermal skeleton; ?appendages; | *Cycliæ*. |

| | |
|---|---|
| No osseous skeleton nor limb-like appendages; | *Marsipobranchii.* |

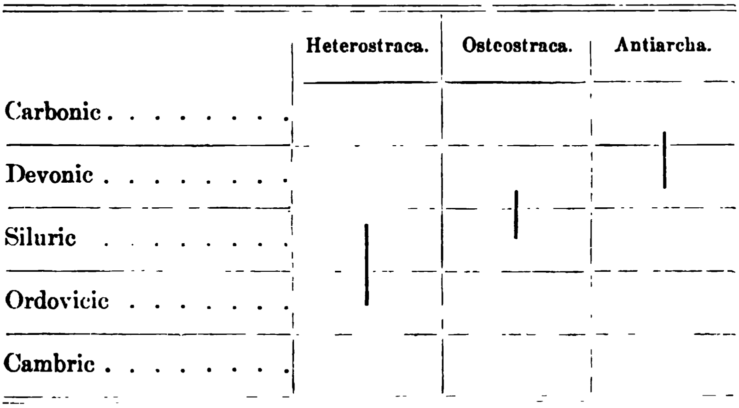
Of the Agnatha, extinct species of the subclasses Ostracophori and Cycliæ only are known.

## Subclass I.—OSTRACOPHORI.

There are three orders of this subclass, as follows. In none of them are nostrils present:

| | |
|---|---|
| No pectoral appendages; exoskeleton in three layers,—the internal lamellar, the middle cancellous, the external vaso-dentine; no bone-corpuscles; | *Heterostraca.* |
| No pectoral appendages; exoskeleton in three layers with bone-corpuscles, the middle layer with vascular canals; | *Osteostraca.* |
| Pectoral appendages; exoskeleton osseous; with sensory grooves; | *Antiarcha.* |

The time of appearance and range in time of these orders is displayed in the following table. They are all Paleozoic.



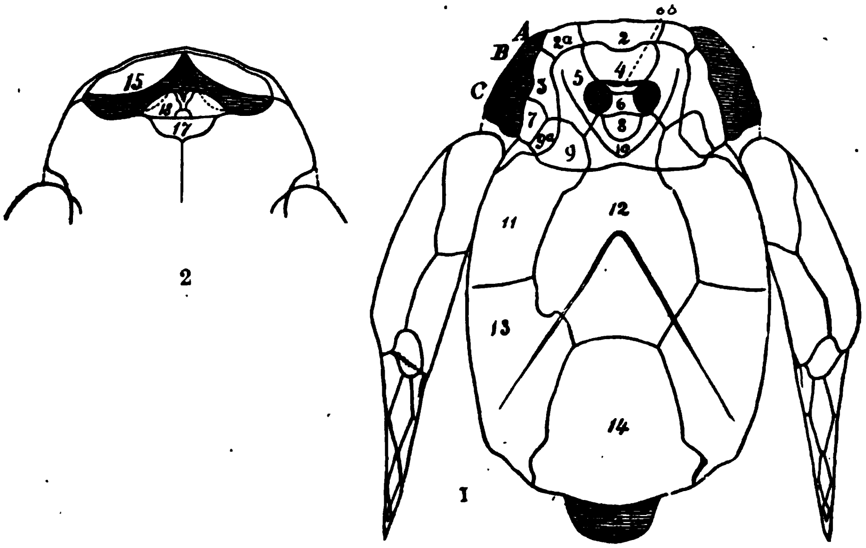


FIG. 2—*Bothriolepis canadensis* Whiteaves; head and carapace, from above, and head from below. From the Devonic of New Brunswick. From Whiteaves. (Antiarcha.)

The Ostracophori are the oldest known Agnatha, and the oldest Ostracophori have been found in the Siluric, in the Salina of Pennsylvania and the Ludlow rocks of England, which have produced Heterostraca. The Osteostraca appear first in the Ludlow beds in England, and extend to the Lower Devonic (Old Red Sandstone). They appear first in America at the latter horizon in New Brunswick. The Antiarcha commence in the Old Red, and continue into the Chemung of the Lower Carbonic system. The principal genus of the Heterostraca is the Pteraspis; of the Osteostraca is the Cephalaspis; and of the Antiarcha is the Pterichthys. (Fig. 2.)

## Subclass II.—CYCLIÆ.

Median diphycercal caudal fin; brain case not segmented; *Saccocephala.*

The order SACCOCEPHALA is the only one known to pertain to the Cycliæ. It embraces the simple family of the Paleospondylidæ based on the genus Paleospondylus, which has been, so far, only found in the Carboniferous beds of Scotland.

## Subclass III.—MARSIPOBRANCHII.

This subclass has two orders:

Branchial fissures communicating directly with the pharynx; nasal sac perforating the palate; *Hyperotreti.*

Branchial fissures communicating with a common branchial passage which opens into the pharynx; nasal sac not perforating palate; *Hyperoarti.*

To the Hyperotreti belong two families, the Myxinidæ and the Bdellostomidæ; to the Hyperoarti one, the Petromyzontidæ.

No extinct species of Marsipobranchii are known. They include only the recent lampreys and hags.

## Class II.—PISCES.

This class is divided into four subclasses:

I. No maxillary arch.

A. No dermal cranial ossifications nor opercular bones; claspers present (in living forms).

A hyomandibular; palatopterygoid arch distinct; *Elasmobranchii.*

No hyomandibular; palatopterygoid arch fused with chondrocranium; *Holocephali.*

AA. Dermal cranial ossifications and opercular bones present; no claspers.

Suspensorium fused with chondrocranium; palatopterygoid arch free; *Dipnoi.*

II. A maxillary arch present.

Dermal cranial bones and opercula present; no claspers; suspensorium distinct from cranium; palatopterygoid arch free; *Teleostomi.*

With our present knowledge we find the first appearance of these subclasses to be contemporary; *i. e.*, in the earlier part of the Devonic system, in the Corniferous Limestone and its equivalents in other parts of the world. Spines, possibly belonging to sharks (Onchus), have been found in Lower Siluric (Clinton) in Pennsylvania, and the Upper Siluric (Ludlow) in England, but the animals to which they belong may not have been Pisces. The Devonic forms referred to the Dipnoi (the Arthrodira), while probably belonging to that subclass, are not yet positively proven to be such. Representatives of all four subclasses still exist. The Elasmobranchii are seen in the sharks and rays; the Holocephali in the Chimæras; the Dipnoi in the lung-fishes; and the Teleostomi in the true fishes.

The primary divisions of the fishes, as above indicated, are seen in the structure of the skull. After this the structure of the fins demands attention. Some of the peculiarities of fin structure are common to all the members of a subclass, while others characterize subdivisions of the same. These members consist of a dermal portion and a skeletal portion. The former is external to the body-walls; the latter is internal to those walls in the case of the median fins, and external in the paired fins, when present. The skeletal portion consists of two sets of segments. First those to which the dermal rays or folds are attached are called the basilars. These are articulated to a second set, the axials. The segments are then termed the baseosts and axonosts. In the paired fins the latter are articulated directly with the elements of the shoulder and pelvic girdles. Of the latter only the pubic element is present in Teleostomi. In the shoulder girdle we have elements termed scapula, coracoid, clavicle, and epiclavicle. There is sometimes an interclavicle. The dermal portion of the fins may include as supports certain "fin-rays," or it may include only hair-like rods or "actinotrichia." The latter characterize primitive types. In the case of the median fins it is characteristic of primitive fishes to have the baseosts and axonosts articulated with the neural spines of the vertebræ. In modern fishes the axonosts are not so articulated, and do not correspond with them, while the baseosts are rudimental or wanting. (Fig. 3.)

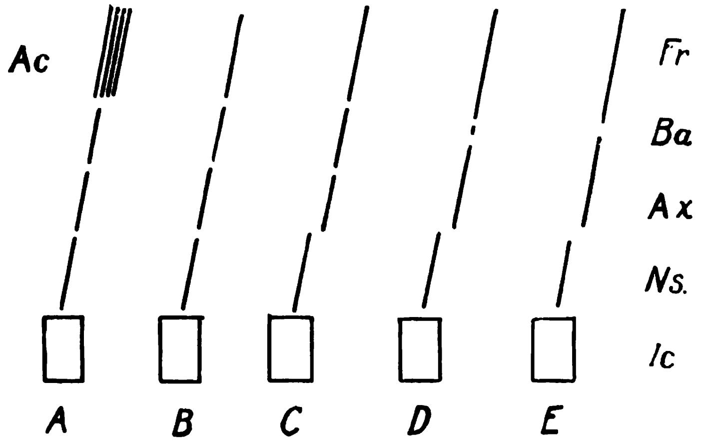
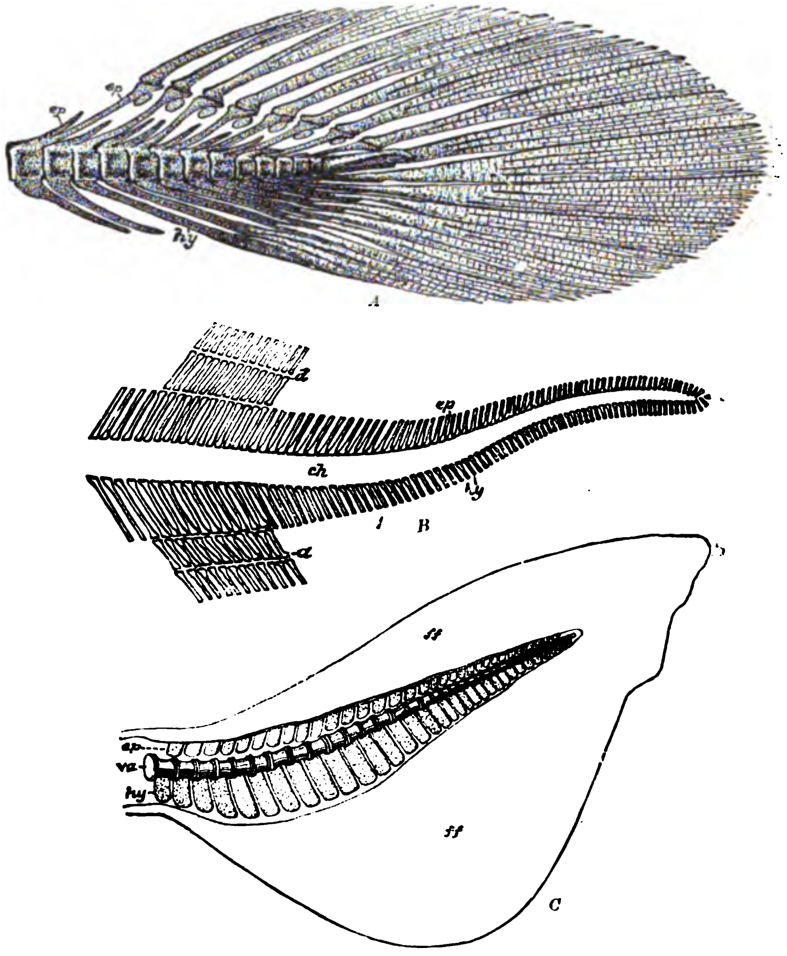


FIG. 3.—Diagrams of actinophores; *A*, entotetramerous; *B*, ectetramerous; *C*, *D*, ectrimerous; *E*, ecdimerous; *Ac*, actinotrichia; *Fr*, fin-rays; *Ba*, baseost; *Ax*. axonost; *Ic*, intercentrum.

Remarkable modifications take place in the successive evolution of the caudal fin. The primitive condition of the vertebral column in the tail of a fish is straight, with spines equally divergent above and below. This is the diphycercal tail (Fig. 4, *A*). It persists in some modern fishes, *e. g.*, the eels. In the next stage the axis is turned up at the end, and the spines of the inferior side are spread out fan-like, while those of the superior side are crowded together. The dermal part of the fin may develop an angle on the inferior spines (hæmal spines), the result being a two-lobed fin, in which the upper lobe is much larger than the lower.

This is the heterocercal tail (Fig. 4, *B*, *C*, and *D*). In later forms the hæmal spines grow larger and the neural spines smaller, and the axis grows shorter by the abortion of the terminal centra. As a result, the lobes of the caudal fin become equal. In the most fully developed types the hæmal spines fuse into a fan-shaped bone which supports the fin. This is the homocercal caudal fin (Fig. 3, *E*). In its growth it generally passes through the diphycercal and heterocercal stages before reaching maturity.



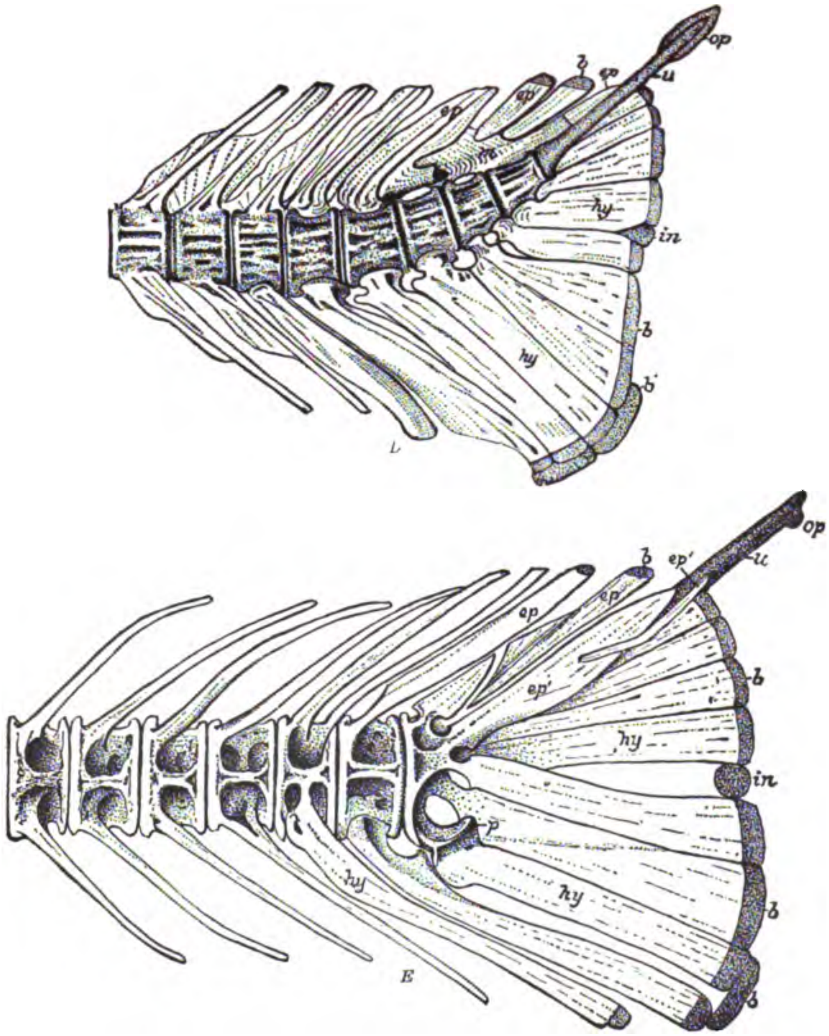


**FIG. 4.**—Tails of fishes; *A*, diphycercal tail of Polypterus; *B*, diphyheterocercal tail of Coccosteus; *C*, caudal fin of a shark (Centrina); *D*, end of vertebral column of trout (*Salmo fario*); *E*, end of vertebral column of barbel (*Barbus fluviatilis*); *ep*, Epural; *hy*, hypural bones.

## Subclass I.—ELASMOBRANCHII.

The sharks are divided into three orders, as follows:

Paired fins ptychopterygial; with axonosts (metapterygium) enclosed in body-wall and basilars only free; *Acanthodii.*

Paired fins archipterygial; unibasal; a basioccipital element; *Ichthyotomi.*

Paired fins pluribasal (tribasal); no basioccipital element; *Selachii.*

The order ACANTHODII presents the most primitive type of paired fins known in the Pisces. The vertebral axis is notochordal, and the fins do not display any actinotrichia or rays. The males have no claspers. Tail heterocercal. In the known genera the fins are supported by a large spine in the anterior border of each; and the integument is covered with small quadrate granules, which also extend over the fins. The teeth are absent or minute, or consist of a single compressed triangular cusp, with smaller laterals.

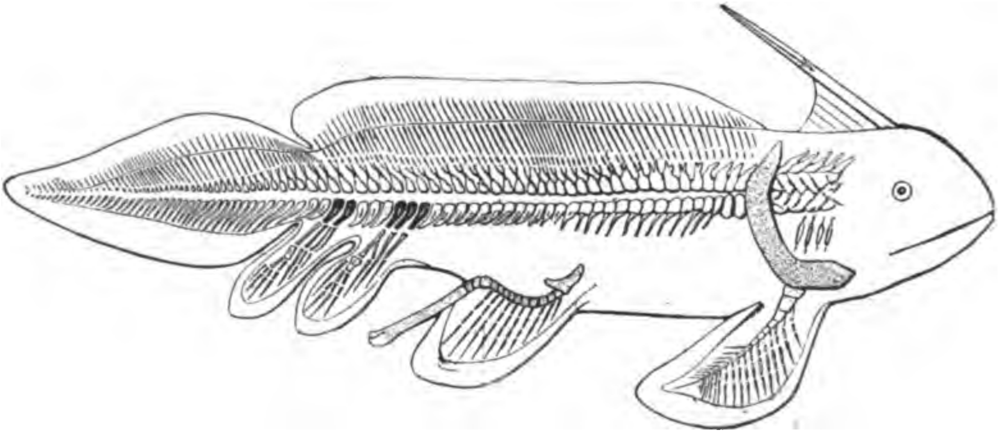


FIG. 5.—*Pleuracanthus lucius* Ag. From the Coal Measures of Alsace. From Sauvage.

The Acanthodidæ have but one dorsal fin, while the Ischnacanthidæ and Diplacanthidæ have two. In the Diplacanthidæ only have clavicles been observed; in the other two families they are wanting. Among Diplacanthidæ the genus Climatius is remarkable in having a series of spines on each side between the ventral and pectoral fins, which indicate the position of the primitive lateral fold, from which the paired fins are supposed to have been derived.

Diplacanthidæ are Devonic, as are also Ischnacanthidæ. Acanthodidæ belong to the Devonic and Carbonic.

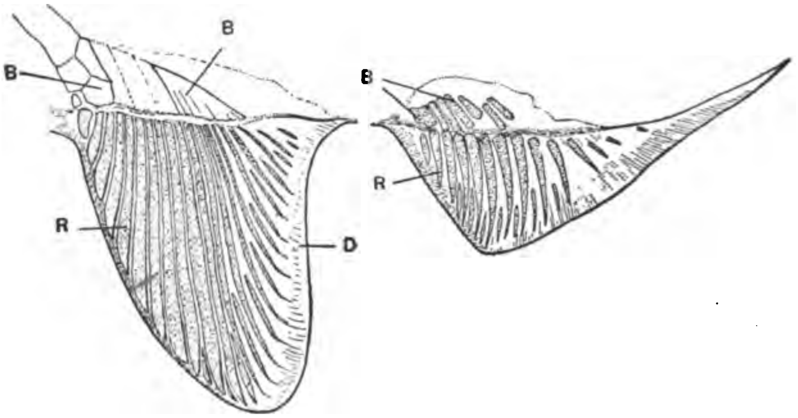


FIG. 6.—Pectoral and ventral fins of Cladoselache x⅓ (from Dean). B, axonosts (meso- and meta-pterygium); R, baseosts; D, dermal portion of fin.

In the ICHTHYOTOMI the notochord persists, and the centra are represented by segments; the neural spines, axonosts, and baseosts are continuous, and the dermal rays are actinotrichia (that is, hair-like and more numerous than the baseosts). There are two families, the Pleuracanthidæ and the Cladodontidæ, which differ in the form of the pectoral fin. In the former they are biserially pinnate (Fig. 5), while in the latter they are uniserially pinnate (branches —baseosts—on one side of the axis—axonosts—only) (Fig. 6.) The Pleuracanthidæ have teeth with two principal equal cusps, while the Cladodontidæ have a principal median cusp, with or without smaller lateral cusps. The Cladodontidæ embrace the largest and most formidable species, and belong to the Carbonic period. The Ichthyotomi are all confined to the Carbonic system.

The SELACHII (sharks and rays) present two lines of relation, or suborders, which differ as follows:

| | |
|---|---|
| Vertebræ, when developed, having the concentric laminæ predominating over the radiating laminæ; anal fin absent; | *Tectospondyli.* |
| Vertebræ when developed, with the radiating laminæ predominating over the concentric; anal fin present; | *Asterospondyli.* |

In the *Tectospondyli* the majority of living types have the body depressed, so that the branchial fissures are on the inferior surface. This type is seen in the skates, sawfishes, and rays. In the *Asterospondyli*, on the other hand, the branchial fissures are lateral. There are several families of Tectospondyli, which appeared at different periods of geological time. They are as follows:

I. Snout unarmed.

A, The crowns of the teeth closely overlapping each other like shingles.

Edges of crowns forming a grinding face; (1) *Petalodontidæ.*

AA, The crowns of the teeth not overlapping.

β. Summits of crowns forming a grinding surface.

(2) *Psammodontidæ.*
(3) *Rajidæ.*
(4) *Rhinobatidæ.*
(5) *Trygonidæ.*
(6) *Myliobatidæ* (eagle rays).

ββ. Summits of crowns elongate cusps.

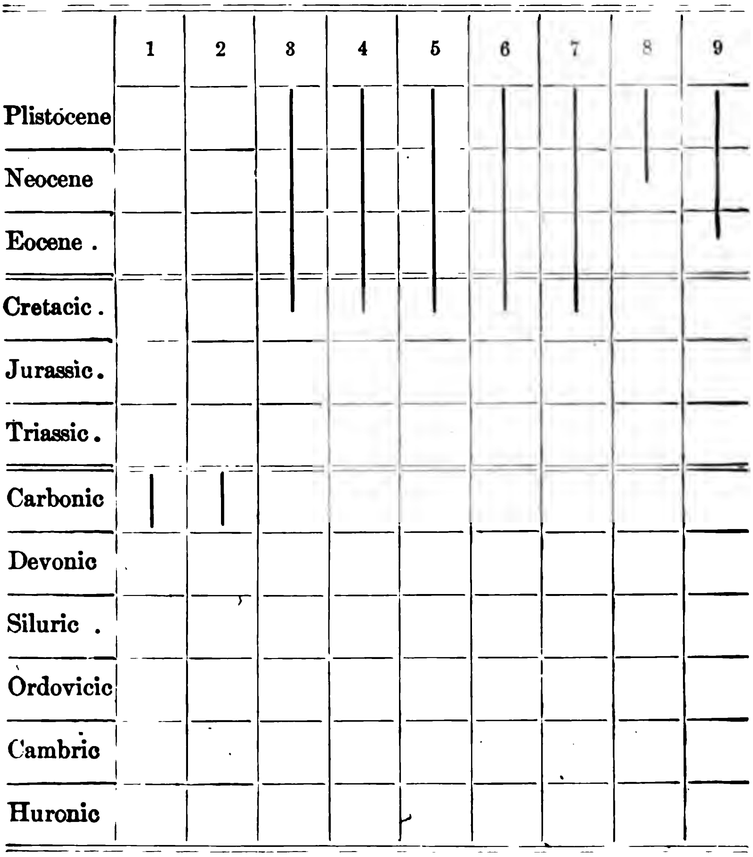
Body not flattened; (7) *Spinacidæ.*

II. Snout produced into an ensiform weapon toothed on both sides.

(8) *Pristiophoridæ.*

(9) *Pristidæ* (saw-fishes).

These families have the following range in geological time:



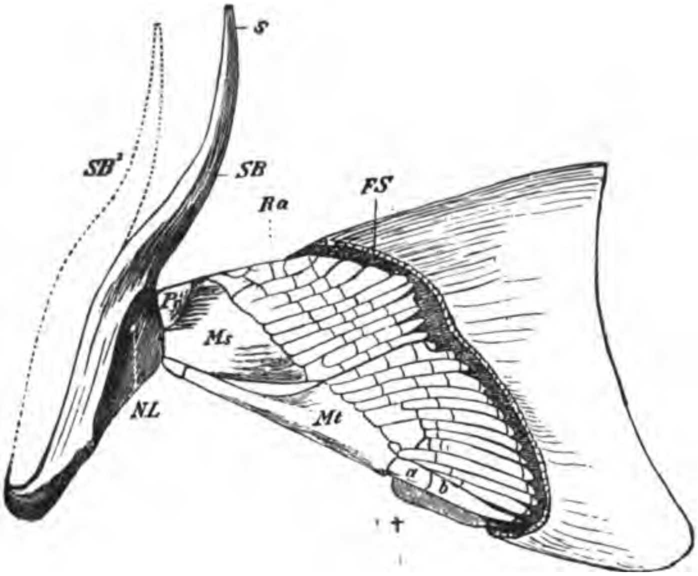


FIG. 7.—*Heptanchus griseus* left pectoral fin, pluribasal type; *SB*, scapular arch; *NL*, foramen; *Pr*, propterygium; *Ms*, mesopterygium; *a*, *b*, axis of metapterygium; *Ra*, basilars; *FS*, actinotrichia. From Wiedersheim.

The families of the Asterospondyli differ as follows:

I. Teeth molariform.*

Teeth separate; (1) *Cestraciontidæ.*

Teeth confluent; (2) *Cochliodontidæ.*

II. Teeth with elevated cusps.

(3) *Hexanchidæ* (Fig. 7).

(4) *Scylliidæ.*

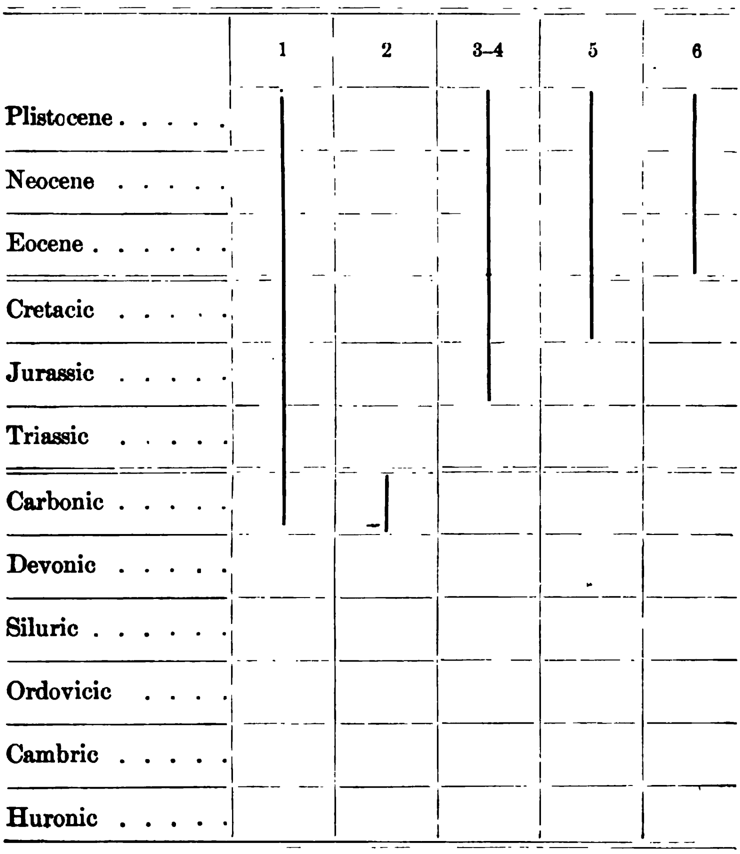
(5) *Lamnidæ.*

(6) *Carchariidæ.*

The distribution of these families in time is as follows:

---

* Except some Cestraciontidæ.



From these tables it appears that the Selachii with grinding teeth are prior in geological age to those with teeth especially appropriate to a carnivorous diet. The latter reached their greatest perfection, as well as size and numbers, in the Neocene system, some of the Carcharodons having been probably seventy feet in length.

All the families of Elasmobranchii are common to the Old and New Worlds.

## Subclass II.—HOLOCEPHALI.

But one order of this class is known:

A single external branchial fissure; actinotrichia present; basilars, axonosts, and neural spines articulating with each other; pectoral fin pluribasal, with three axonosts and numerous basilars; ventrals with elongate axonosts and basilars; *Chimæroidei.*

In all known CHIMÆROIDEI the teeth are large paired bodies, one pair in the lower and two in the upper jaws, composed of coarse vascular dentine. These contain columns varying in number and shape, consisting of coarse tubes with calcareous walls which terminate on the masticating surfaces. Notochord persistent, the ossifications, when present, consisting of delicate rings, more numerous than the neural arches. In the existing forms the males have claspers like those of sharks.

Chimæroidei appear in the Corniferous Limestone in Ohio, Wisconsin and Iowa, and in the Eifel Limestone in Rhine Prussia. They are found in Triassic and Jurassic beds in Europe, and abound in the Cretacic of Europe and North America, and New Zealand. They extend through the Cenozoic beds of Europe and North America, and a few species still exist. The known families are the Ptychodontidæ (of doubtful reference), the Squalorajidæ, Myriacanthidæ, and Chimæridæ, the last named only still remaining alive, in four genera.

## Subclass III.—DIPNOI.

Two orders of this subclass are known, as follows:

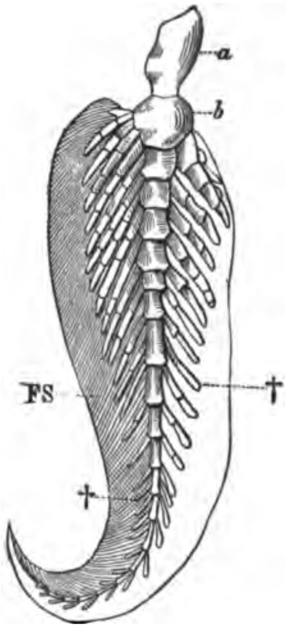


Fig. 8.—*Ceratodus forsteri* Krefft; pectoral fin, unibasal type; *a*, *b*, axial elements; †, radials; *FS*, actinotrichia. From Wiedersheim.

| | |
|---|---|
| Paired fins rudimentary or absent; pelvic elements (so far as known) double, lateral; body more or less protected by plates; | *Arthrodira.* |
| Paired fins archipterygial (*i. e.*, unibasal); pelvic elements fused on the middle line; body without bony plates (Fig. 8); | *Sirenoidea.* |

The Arthrodira are represented by three or four families, the Coccosteidæ, the Asterosteidæ, and the Mylostomidæ, all restricted to the periods of the Devonic system. Their remains abound in these horizons of Europe and North America. They possess, behind the head, a segmented dorsal plate and a compound ventral plate or plastron. The anterior lateral superior plates articulate with the posterior lateral cranial elements by a hinge-like joint. Notochord persistent. These forms have some resemblance to the Agnatha Antiarcha, but they have a well-developed mandibular arch, and distinct pelvic elements. Their teeth are processes of the edges of the jaws.

The Sirenoidea commence in the Carbonic system and continue to the present day, when representatives of two genera, Ceratodus and Lepidosiren, exist in the fresh waters of the Southern Hemisphere. The families are four, the Dipteridæ, Phaneropleuridæ, and Ctenodontidæ, where the skull is covered with small tessellated plates, and the Lepidosirenidæ, where the bones of the skull are few and large. The Dipteridæ and Phaneropleuridæ are confined to the Devonic, and the Ctenodontidæ to the Carbonic. The Lepidosirenidæ commence in the Permian (Texas) and continue to the present time. The teeth of Sirenoidea are plates with radiating ridges, or else processes of the jaws.

## Subclass IV.—TELEOSTOMI.

There are four superorders of the Teleostomi or true fishes, which differ in the structure of the fins:

I. Median fins each with a single bone representing axonosts.

Paired fins unibasal; *Rhipidopterygia.*

II. Median fins with numerous axonosts.

All paired fins with baseosts; pectorals only with a distinct peduncle formed of axonosts; *Crossopterygia.*

All paired fins with baseosts; neither with distinct peduncle of axonosts; *Podopterygia.*

Axonosts not forming a peduncle; pectorals only with developed baseosts; *Actinopterygia.*

### Superorder RHIPIDOPTERYGIA.

The orders of Rhipidopterygia are the following. They all have actinotrichia in place of fin-rays:

I. Paired fins with the basilars arranged on each side of the median axis, or archipterygial.

Median fins with basilars; *Taxistia.*

II. Paired fins with the basilars arranged fan-shaped at the end of the short axis.

| | |
|---|---|
| Median fins with basilars; | *Rhipidistia.* |
| Median fins without, caudal fin with, basilars; | *Actinistia.* |

The Taxistia includes but one family, the Holoptychiidæ, which is of Devonic age.

The Rhipidistia includes the Tristichopteridæ, from the Devonic and Carbonic; the Osteolepidæ, from the same; and possibly the Onychodontidæ, which are Devonic.

The Actinistia includes the single family of the Cœlacanthidæ, which appears in the Lower Carbonic and ranges to the Upper Cretacic, in both Europe and America. (Fig. 9).

In all of the Rhipidopterygia the tail is either heterocercal or diphycercal, and the chorda dorsalis persists. The scales have a layer of ganoine, which extends also on the head. The latter has a well-defined, persistent transverse suture separating the parietal from the frontal elements.

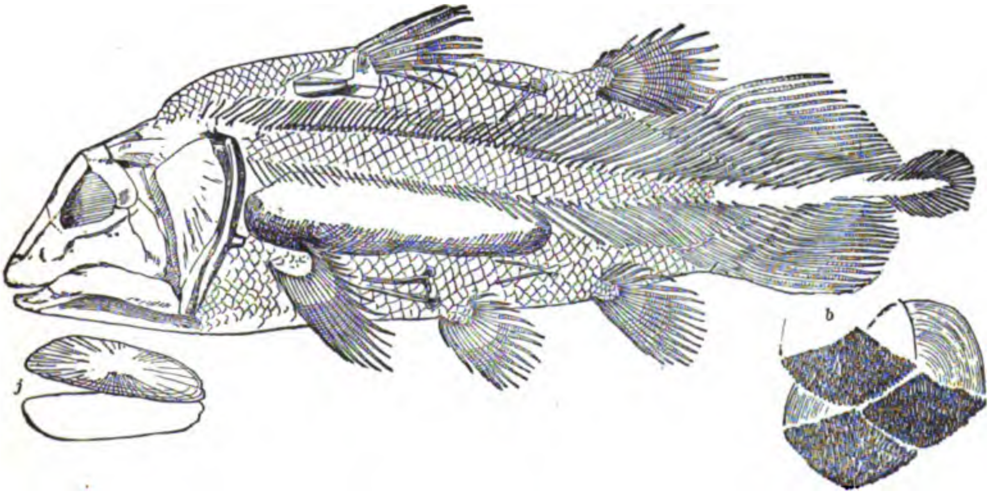


**Fig. 9**—***Undina penicillata*** Münst. (Cœlacanthidæ); one-third natural size, showing rhipidopterygiar and actinistious types of fins; *j*, jugular plates; *b*, scales of *Unidina acutidens*. From Zittel.

### Superorder CROSSOPTERYGIA.

The superorder CROSSOPTERYGIA includes two orders, as follows:

| | |
|---|---|
| Baseosts and axonosts well developed; actinotrichia; no fin-rays; pectorals? unibasal; | *Haplistia.* |
| Baseosts rudimental; fin-rays; pectorals tribasal; | *Cladistia.* |

But one family is included in the Haplistia, the Tarasiidæ, from the Lower Carbonic of Scotland. The Cladistia are represented by a family which is not known in the fossil state, the Polypteridæ of the rivers of Africa. The vertebræ in this family are ossified and biconcave.

### Superorder PODOPTERYGIA.

The superorder PODOPTERYGIA has also two orders. They are thus defined:

| | |
|---|---|
| Branchiostegal rays present; | *Lysopteri.* |
| Branchiostegal rays absent; | *Chondrostei.* |

In these orders the notochord is persistent, and there are either actinotrichia, or fin-rays, which are more numerous than the baseosts. Tail heterocercal or diphycercal.

The Lysopteri includes four families, which differ as follows:

| | |
|---|---|
| I. Tail heterocercal. | |
| Teeth acute, external; | *Palæoniscidæ.* |
| Teeth obtuse, on palate and splenial; | *Platysomidæ.* |
| No teeth; | *Chondrosteidæ.* |
| II. Tail diphycercal. | |
| Teeth present; scuta on body; | *Belonorhynchidæ.* |

The Palæoniscidæ range from the Devonic to the Jurassic inclusive; the Platysomidæ belong to the Carbonic exclusively; the Belonorhynchidæ to the Trias; and the Chondrosteidæ to the Jurassic.

The Chondrostei are degenerate representatives of the

Podopterygia. They are deficient in various normal ossifications, and have an additional series of membrane bones in the middle line of the skull. The two families are the Acipenseridæ, or sturgeons, and the Polyodontidæ, or paddle-fishes. Both are represented at the present day in the northern regions of both hemispheres, and both appear first in geological time in the Eocene system.

### Superorder ACTINOPTERYGIA.

In this superorder we have the finally specialized type of the true fishes. This consists in the abbreviation of the skeletal parts of the true fins, so that the basilar elements become sessile on the scapula. (Fig. 10.) Coincidentally with this result, the fin-rays of the median fins become distinctly developed and articulated each with its corresponding baseost or axonost. Fishes of this superorder have, for the most part, homocercal tails, the superior lobe being contracted to the size of the inferior lobe, and the vertebræ ossified; but in some of the lower and older types both heterocercal tails and notochordal vertebræ still remain. Diphycercal tails also continue well along the ascending scale.

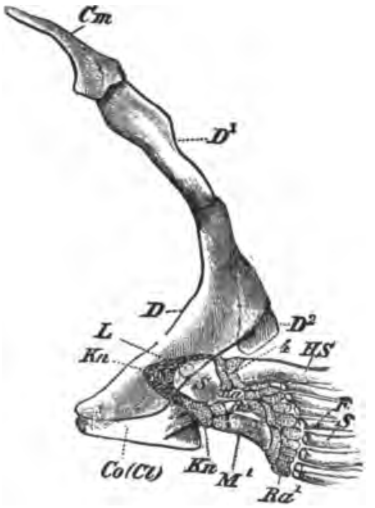


FIG. 10.—*Salmo fario L;* left shoulder-girdle; *Cm*, posttemporal; *D 1*, epiclavicle; *D*, clavicle; *D 2*, postclavicle; *S*, scapula; *Co* (*Cl*), coracoid; *Ra*, basilars; *L*, scapular foramen; *HS*, *FS*, fiin-rays.

The Actinopterygia fall into two tribes:

Ventral fins abdominal; a ductus pneumaticus; no spinous dorsal fin; parietal bones not usually separated by supraoccipital; scales usually cycloid; *Malacopterygia.*

Ventral fins usually thoracic or jugular;
no ductus pneumaticus; usually a
spinous dorsal fin; parietal bones usually separated by the supraoccipital;
scales usually ctenoid; *Acanthopterygia.*

In the cartilaginous fin-rays and posterior ventral fins the Malacopterygia more nearly approach the fishes of the superorders considered in the preceding pages, than do the Acanthopterygia. The persistence of the communication between the swim-bladder and the gullet (ductus pneumaticus) is another indication of this affinity. Accordingly we find representatives of the former in older periods than we do the latter. They are abundant in the Jurassic and Cretacic and later periods, while the Acanthopterygia are very rare in the Cretacic, and are abundant first in the Eocene.

The orders of the Malacopterygia are the following:

I. Median fins with actinotrichia.

Basilars of median fins well developed;
notochord persistent; (1) *Docopteri.**

II. Median fin-rays equal to and articulating with axonosts.

A. Metapterygium present; anterior vertebræ unmodified. (Holostei).

*a*, Vertebræ complex, the pleurocentra
and intercentra distinct.

Anterior vertebræ similar to others; (2) *Merospondyli.*

*aa*, Vertebræ with centra and intercentra complete on part of the column at least; amphicœlous;

Anterior vertebræ similar; (3) *Halecomorphi.*

*aaa*, Vertebræ (intercentra) opisthocœlous.

---

* The position of this order is uncertain,

Anterior vertebræ similar; a precoracoid arch and a coronoid bone; (4) *Ginglymodi.*

AA. No metapterygium; anterior vertebræ modified, and with ossicula; vertebræ amphicœlous. (Ostariophysæ).

β, A precoracoid arch.

γ, No symplectic bone.

Anterior vertebræ modified, and with ossicula auditus; pterotic simple; parietals not distinct; (5) *Nematognathi.*

γγ, A symplectic bone.

Anterior vertebræ coössified, and with ossicula auditus; pterotic simple; parietals distinct; (6) *Plectospondyli.*

ββ, No precoracoid arch.

Parietals present, distinct, not separated by supraoccipital; (7) *Glanencheli.*

AAA. No metapterygium; vertebræ amphicœlous, the anterior not modified and without accessory ossicles. (Teleocephali).

β, Scapular arch suspended to cranium.

α, A symplectic.

γ, A precoracoid arch.

Pterotic annular, including a cavity which is closed by a distinct bone; parietals distinct, not separated by supraoccipital; (8) *Scyphophori.*

Pterotic simple; parietals distinct, not separated by supraoccipital; (9) *Isospondyli.*

Eight pectoral basilar bones, the external pair opposite each other, all articulating with the scapula; (10) *Actinochiri.*

γγ, No precoracoid arch.

Pterotic simple; parietals separated by supraoccipital; baseosts distinct; (11) *Haplomi.*

*αα*, No symplectic.

Baseosts fused into a single cartilage; (12) *Xenomi.*

Pterotic simple; parietals distinct, in contact; a preoperculum and palatine arch; (13) *Ichthyocephali.*

ββ, Scapular arch free from cranium.

δ, A symplectic bone.

Hyoid arches and pectoral baseosts developed; (14) *Holostomi.*

δδ, No symplectic.

Opercular bones and five osseous branchial arches, with ceratohyal; (15) *Enchelycephali.*

Opercular bones and one osseous branchial arch, and ceratohyal; (16) *Colocephali.*

No opercular bones, nor ceratohyal, nor osseous branchial arches; (17) *Lyomeri.*

The families of the Malacopterygia are as follows:

Docopteri: Dorypteridæ.

Merospondyli: Sauropsidæ; Pycnodontidæ; Stylodontidæ; Sphærodontidæ; Macrosemiidæ.

Halecomorphi: Amiidæ (dog-fishes).

Ginglymodi: Lepidosteidæ (bony gars).

Nematognathi: Siluridæ (cat-fishes); Hypophthalmidæ; Aspredinidæ.

Plectospondyli: Characinidæ; Sternopygidæ; Cobitidæ; Cyprinidæ (carp); Catostomidæ (suckers).

Glanencheli: Gymnotidæ (electric eels).

Scyphophori: Mormyridæ; Gymnarchidæ.

Isospondyli: Dapediidæ; Lepidotidæ; Aspidorhynchidæ; Saurodontidæ (Fig. 11); Osteoglossidæ; Heterotidæ; Galaxiidæ; Clupeidæ (herring); Chirocentridæ; Salmonidæ (salmon); Thymallidæ (grayling); Alepocephalidæ; Gonorhynchidæ; Sauridæ; Lutodiridæ; Aulopidæ; Elopidæ; Albulidæ; Hyodontidæ; Notopteridæ.

Actinochiri: Erisichthidæ.

Haplomi: Esocidæ (pike); Stratodontidæ; Umbridæ; Cyprinodontidæ; Amblyopsidæ (blind fishes).

Xenomi: Dalliidæ.

Ichthyocephali: Monopteridæ.

Holostomi: Amphipnoidæ.

Enchelycephali: Nemichthyidæ; Anguillidæ (eels); Congridæ (eels); Synaphobranchidæ; Simenchelyidæ.

Colocephali: Muraenidæ (eels).

Lyomeri: Saccopharyngidæ; Eurypharyngidæ.

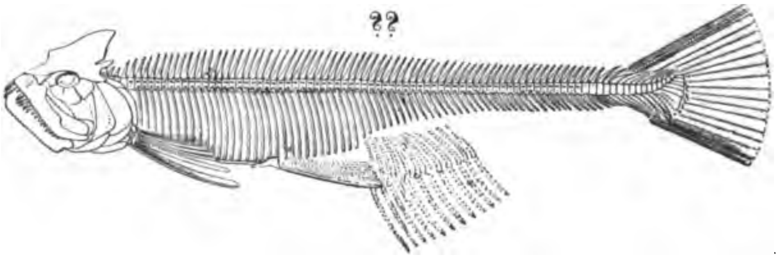
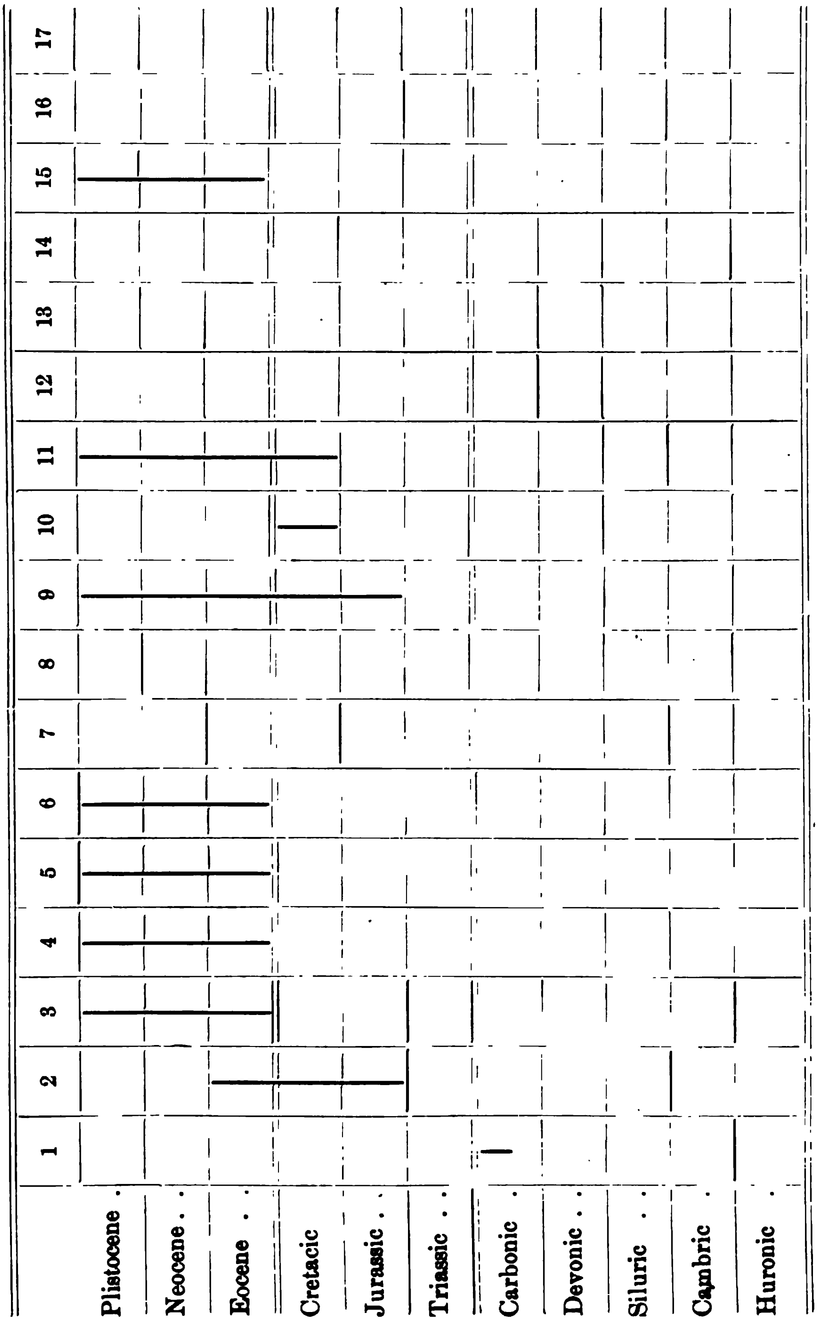


**Fig. 11.—*Portheus molossus*, Cope; isospondylous fish from the Upper Cretacic of Kansas, one-twentieth natural size. Original.**

The geological range of the orders of the Malacopterygia is as follows:


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Plistocene . .
Neocene . .
Eocene . .
Cretacic
Jurassic . .
Triassic . .
Carbonic .
Devonic . .
Siluric . .
Cambric .
Huronic .

The orders of which no record is given are known only in the living state. The Plectospondyli represent the highest form of the Malacopterygia, while the Haplomi give the connection with the Acanthopterygia through the Percesoces of the latter. Tne Isospondyli offer the connection with the Merospondyli. The Apodal line (the eels), including orders Nos. 13 to 17, is a degenerate one, ending in the greatly degenerate deep-sea forms of the Lyomeri.

The orders of the Acanthopterygia are the following:

A. Scapular arch suspended posterior to the cranium.

Maxillary bone distinct; no interclavicles; epibranchials and pharyngeals present; inferior elements distinct; (1) *Opisthomi.*

AA. Scapular arch suspended to cranium by a posttemporal bone.

*a*, Ventral fins abdominal.

Branchial arches developed, third superior pharyngeal enlarged; gill-fringes linear; no interclavicles; (2) *Percesoces.*

Epibranchials and superior pharyngeals reduced in number; gill-fringes linear; interclavicles present; (3) *Hemibranchii.*

Epibranchials and superior pharyngeals wanting; gill-fringes in tufts; (4) *Lophobranchii.*

*aa*, Ventral fins thoracic or jugular.

*β*, Anterior (spinous) dorsal fin expanded into transverse laminæ, sessile on cranium.

Cranium normal; (5) *Discocephali.*

*ββ*, Spinous dorsal fin not transversely expanded.

γ, Posttemporal projecting freely from skull.

First vertebra united by suture to cranium; intercalaria united behind supraoccipital; basilar pectoral bones elongated; (6) *Pediculati.*

Posterior cephalic region normal; the anterior twisted so as to bring both orbits on one side; inferior pharyngeals distinct; (7) *Heterosomata.*

Cranium normal, premaxillaries usually coössified with maxillaries behind, and the dentary with the articular; pharyngeal bones distinct; (8) *Plectognathi.*

Cranium normal; bones of jaw distinct; (9) *Percomorphi.*

γγ, Posttemporal an integral part of the skull.

Cranium normal; bones of jaws distinct; pharyngeals separate; (10) *Craniomi.*

The families of the preceding orders are as follows:

OPISTHOMI: Mastacembelidæ; Notacanthidæ.

PERCESOCES: Opheocephalidæ; Mugilidæ (mullets); Atherinidæ; Sphyrænidæ (barracuda); Scombresocidæ (soft gar).

HEMIBRANCHII: Pegasidæ; Gasterosteidæ (stickle-back); Fistulariidæ; Centriscidæ; Amphisilidæ; Dercetidæ.

LOPHOBRANCHII: Solenostomidæ; Syngnathidæ (pipe-fishes); Hippocampidæ (sea-horses).

DISCOCEPHALI: Echeneididæ (remoras).

PEDICULATI: Antennariidæ; Lophiidæ (fishing frog).

HETEROSOMATA: Pleuronectidæ (flat-fishes).

PLECTOGNATHI: Triacanthidæ; Balistidæ (trigger-fishes); Tetraodontidæ (bladder-fishes); Diodontidæ; Ostraciidæ.

PERCOMORPHI: (Anacanthini) Ophidiidæ; Gadidæ (cod); Macruridæ; (Haplodoci) Batrachidæ (toad-fishes); (Cyclopteroidea) Cyclopteridæ; (Scatophagoidea) Scatophagidæ; (Epilasmia) Acronuridæ; Chætodontidæ; (Rhegnopteri) Trichidiontidæ; (Distegi) Scorpænidæ; Cottidæ (sculpins); Blenniidæ; Gobiidæ; Platycephalidæ; Rhamphocottidæ; Agonidæ; Heterognathidæ; Gerreidæ; Carangidæ (pompano); Sillaginidæ; Pristipomatidæ; Sciænidæ (maigres); Sparidæ; Percidæ (perch); Berycidæ; Scombridæ (mackerel); Trichiuridæ; Xiphiadidæ; (Labyrinthici) Osphromenidæ; Anabantidæ; (Pharyngognathi) Embiotocidæ; Cichlidæ; Labridæ; Scaridæ.

CRANIOMI; Triglidæ (gurnards); Dactylopteridæ.

The table on the following page shows that no order of the Acanthopterygia has become extinct. The Percomorphi display the greatest numbers and importance at the present time. The Lophobranchii and Plectognathi are degenerate types.

The geological distribution of these orders is as follows:

---

NOTE.—The editor is indebted to Prof. Theodore Gill for several important corrections of ambiguities in the definitions, and oversights in the arrangement of the groups of fishes. None of these changes, however, affect the author's views on affinities, etc.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Plistocene . . . | | ┃ | ┃ | ┃ | ┃ | ┃ | ┃ | ┃ | ┃ | ┃ |
| Neocene . . . . | | ┃ | ┃ | ┃ | ┃ | ┃ | ┃ | ┃ | ┃ | ┃ |
| Eocene . . . . | | ┃ | ┃ | ┃ | ┃ | ┃ | | ┃ | ┃ | |
| Cretacic . . . . | | | | | | | | | ┃ | |
| Jurassic . . . . | | | | | | | | | | |
| Triassic . . . . | | | | | | | | | | |
| Carbonic . . . . | | | | | | | | | | |
| Devonic . . . . | | | | | | | | | | |
| Siluric . . . . . | | | | | | | | | | |
| Cambric . . . . | | | | | | | | | | |
| Huronic . . . . | | | | | | | | | | |

## Class III.—BATRACHIA.

There are three subclasses of Batrachia, as follows:

| | |
|---|---|
| Basioccipital, supraoccipital, intercalare, and supratemporal bones present; propodial bones distinct; | *Stegocephali.* |
| Basioccipital, supraoccipital, and supratemporal bones wanting; propodial bones distinct; no urostyle; | *Urodela.* |
| Basioccipital, supraoccipital, intercalare, and supratemporals wanting; frontals and parietals connate; propodial bones connate; lumbosacral vertebræ united into a urostyle; | *Salientia.* |

### Subclass I.—STEGOCEPHALI.

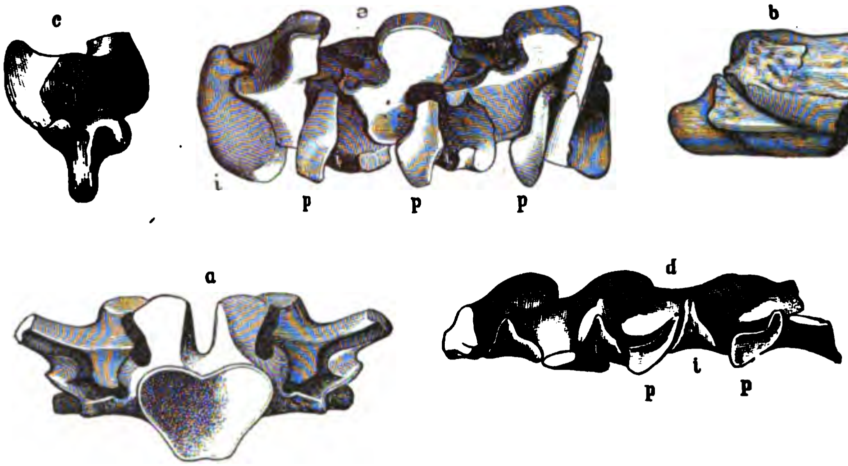
There are four orders of Stegocephali.

*a*, One occipital cotyloid articulation.

| | |
|---|---|
| Vertebral bodies represented by basal and lateral elements (intercentra and centra); | *Ganocephali.* |

*aa*, Two occipital condyles;

| | |
|---|---|
| Vertebræ represented by distinct and incomplete intercentra and centra (pleurocentra); atlas segmented; | *Rhachitomi.* |
| Centra and intercentra complete, making two vertebral bodies to each neural arch; | *Embolomeri.* |
| No centra; intercentra each supporting a neural arch; | *Microsauri.* |



• FIG. 12.—*Trimerorhachis insignis* Cope; parts of skeleton, natural size; *a*, occipital segment with single cotylus; *b*, *c*, posterior part of lower jaw; *d*, *e*, series of vertebræ; *d*, side view, depressed; *e*, view obliquely from above, both showing the rhachitomous structure: *i*, intercentra· *p*, pleurocentra. Original. From the Permian of Texas.

The Stegocephali are only known from the Carbonic and Triassic systems. They are all more or less notochordal, but a considerable range in this respect is found in the Microsauri. In some of them the notochord is cut off by the vertebral ossification, while in others (Branchiosaurus) the ossification is a mere sheath round the chorda. In the Ganocephali and Rhachitomi the vertebral centra are represented by a segment beneath each branch of the neural arch, the pleurocentrum (Fig. 12, *p*); and these rest below on a median inferior piece, the intercentrum (Fig. 12, *i*). In the Embolomeri each of these segments is developed so as to form a disc, so that there are two vertebral bodies to one arch. In the Microsauri the intercentra have been fused with the pleurocentra, so that the body consists principally of the former, and the same structure is characteristic of the remaining Batrachia. In the Reptilia, on the other hand, the intercentra gradually disappear, being represented in most of the types in the cervical and caudal regions only. In the latter they support the chevron bones.

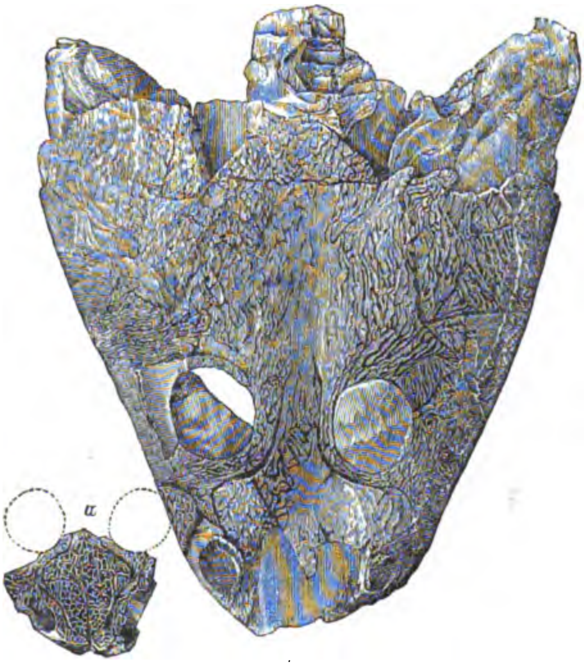


**FIG. 13**—*Trimerorhachis insignis* **Cope; skull. From the Permian bed of Texas. Original.**

Of the GANOCEPHALI two families are known, the Trimerorhachidæ (Figs. 12–13), without, and the Archegosauridæ with neural spines of the vertebræ. They occur in the Coal Measures and the Permian of Europe and North America.

The Rachitomi possesses but one family, the Eryopidæ, which often reached a large size (Fig. 14). These are confined to the Coal Measures. If the Labyrinthodontidæ belong to this order they range also to the Trias inclusive, in both continents.

The Embolomeri includes one family, the Cricotidæ,

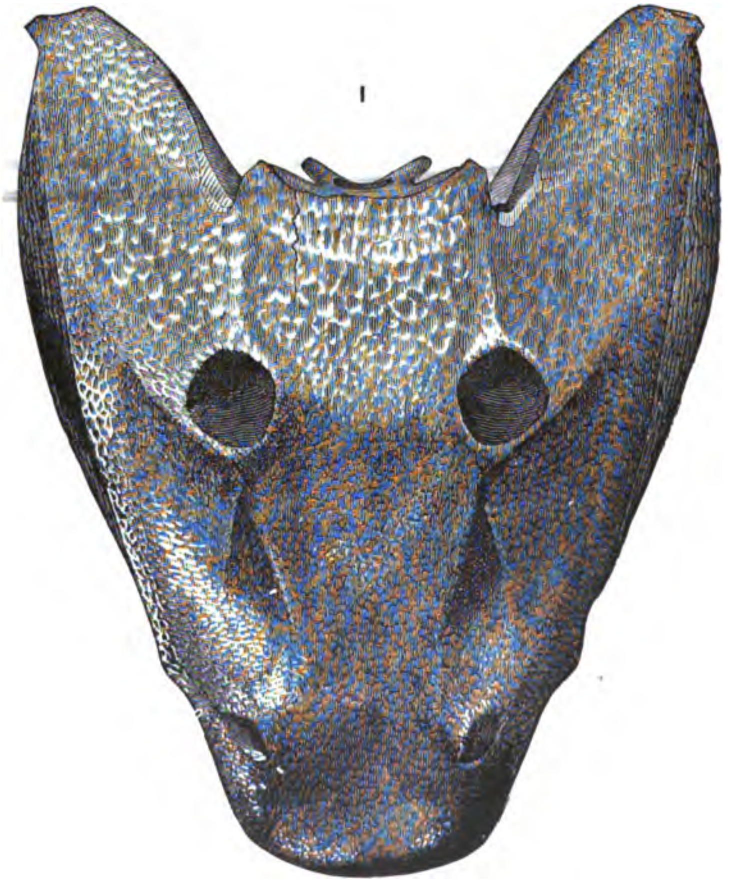


Fig. 14.—*Eryops megacephalus* Cope; skull, from above, one-fourth natural size. From Permian bed of Texas. From Cope.

which belongs to the Permian of Europe and North America. (Fig. 15).

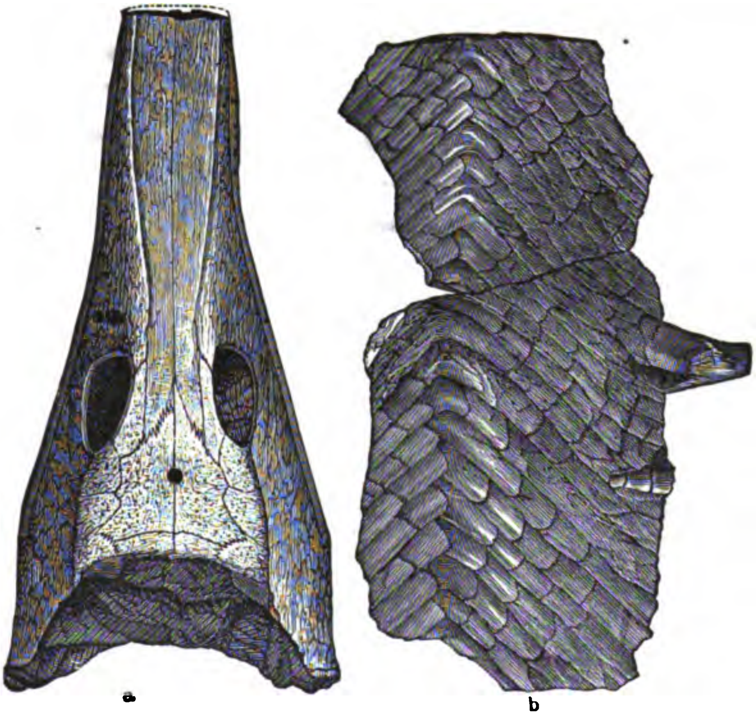


FIG. 15.—*Cricotus heteroclitus* Cope ; one-third natural size. From Permian of Texas, *a*, head from aove ; *b*, part of belly from below. From Cope.

The MICROSAURI embraces the following families: Branchiosauridæ; Hylonomidæ; Molgophidæ; Phlegethontiidæ. The smaller forms are mostly from the Coal Measures, while some large ones occur in the Trias. Some of the Hylonomidæ come from the Permian of North America and Europe. They were mostly of small size, and their vertebræ exhibit very various degrees of ossification. In some the bodies are completely ossified, while in others the ossification forms a superficial layer. In the Labyrinthodontidæ the ossification is more complete. The dentine may be entire, or deeply inflected, so as to form straight or labyrinthic folds.

## Subclass II.—URODELA.

There are three orders of Urodela :

| | |
|---|---|
| *a*, An os intercalare. | |
| Palatine arch and vomer present; | *Proteida.* |
| *aa*, No os intercalare. | |
| A maxillary arch and vomers; | *Pseudosauria.* |
| No maxillary arch or vomers; | *Trachystomata.* |

Under the PROTEIDA the only family known is the Proteïdæ (Fig. 16.)

The PSEUDOSAURIA embraces the following families: Cryptobranchidæ; Amblystomidæ; Hynobiidæ; Plethodontidæ; Thoriidæ; Desmognathidæ; Salamandridæ; Pleurodelidæ; Amphiumidæ; Cæciliidiæ.

The TRACHYSTOMATA includes only the family of the Sirenidæ.

A possible member of the Proteida occurs in the Coal Measures, but certainly known members of the order are not found in a fossil state. Of Pseudosauria fossil forms are first found in the Laramie in America, and they are not uncommon in the Neocene in Europe. Trachystomata are not known fossil.

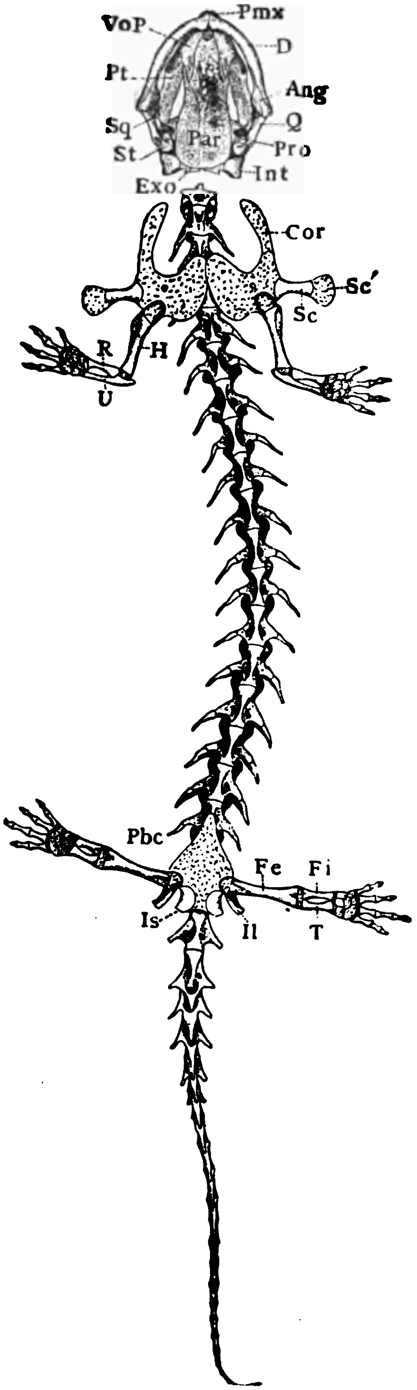


FIG. 16.—*Necturus maculatus* Raf.; skeleton, from below, two-thirds natural size; *Pmx*, premaxillary bone; *Vop*, maxillopalatine; *Pt*, pterygoid; *Sq*, supratemporal; *Q*, quadrate; *Pro*, petrosal; *Int*, intercalare; *St*, stapes; *Exo*, exoccippital; *Par*, parasphenoid; *Ang*, augular; *D*, dentary; *Cor*, coracoid *Sc*, scapula; *Sc′* suprascapula; *H*, humerus; *R*, radius; *U*, ulna; *Pbc*, pubic cartilage; *Fe*. femur; *Fi*, fibula; *T*, tibia; *Il*, ilium; *Is*, ischium.

## Subclass III.—SALIENTIA.

But one order of this subclass is recognized. It is thus defined:

Vomers and palatopterygoid arch present; *Anura.*

The Anura has the families arranged under the following suborders:

Eustachian foramina opening together on the middle line; no tongue; coracoids connected by a cartilage on each side; *Aglossa.*

Eustachian foramina separate; a tongue; coracoids connected by a separate cartilage on each side, one overlapping the other; *Arcifera.*

Eustachian foramina separate; a tongue; a single median cartilage connecting all the coracoids; scapular arch free; *Firmisternia.*

As in Firmisternia, but scapular arch articulated to skull; *Gastrechmia*

The families included under these orders are as follows:

(Aglossa): Xenopidæ; Pipidæ.

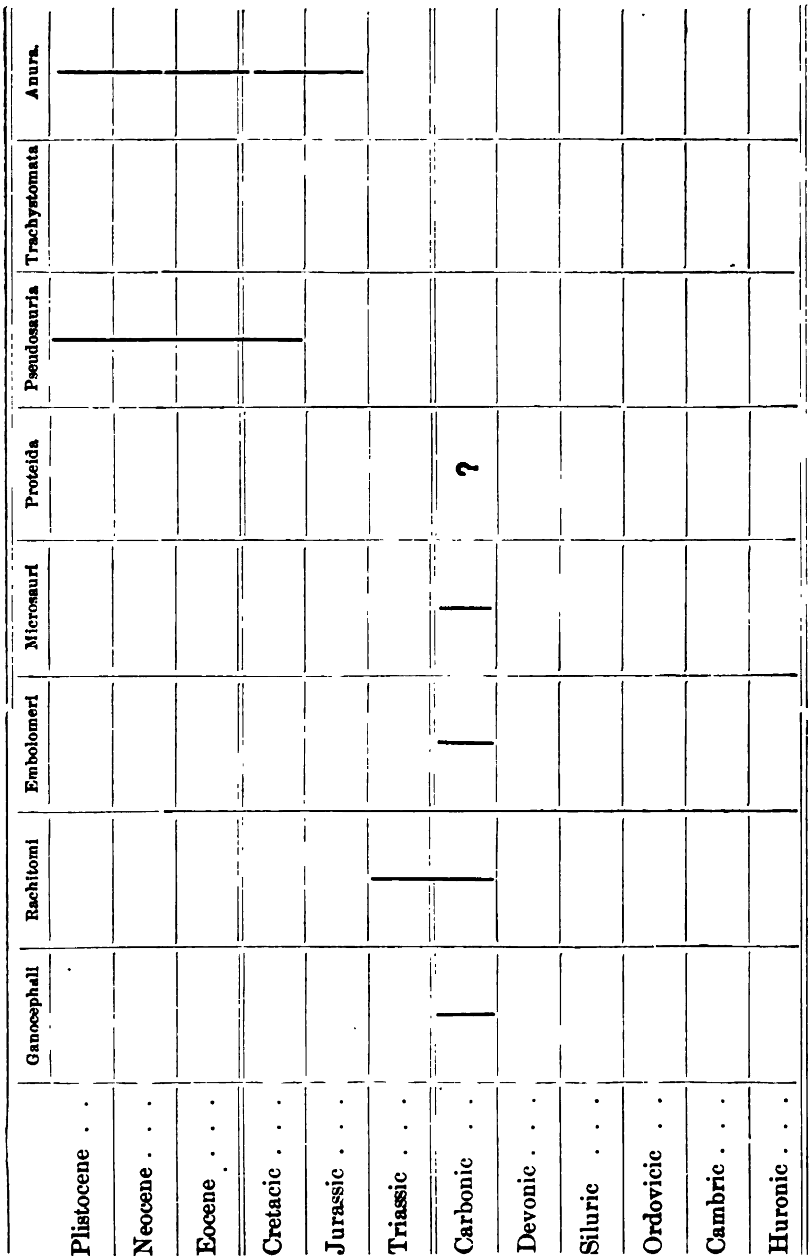
(Arcifera): Discoglossidæ; Bufonidæ; Dendrophryniscidæ; Asterophrydidæ; Pelodytidæ; Scaphiopidæ; Hylidæ; Cystignathidæ; Amphignathodontidæ; Hemiphractidæ.

(Firmisternia): Engystomidæ; Phryniscidæ; Dendrobatidæ; Cophylidæ; Dyscophidæ; Colostethidæ; Ranidæ; Ceratobatrachidæ.

(Gastrechmia): Hemisidæ.

Remains of Anura have been found in the Jurassic beds of Colorado, but to which suborder they pertain is unknown. They next appear in the Eocene of Wyoming. Well defined forms are found in the phosphorites of France, which include both Arcifera and Firmisternia. They continue to the present day.

The time relations of the orders of Batrachia are represented in the preceding table.


Anura
Trachystomata
Pseudosauria
Proteida
Microsauri
Embolomeri
Rachitomi
Ganocephali
Plistocene
Neocene
Eocene
Cretacic
Jurassic
Triassic
Carbonic
Devonic
Siluric
Ordovicic
Cambric
Huronic
?

## Class IV.—MONOCONDYLIA.

There are two subclasses of Monocondylia:

| | |
|---|---|
| Anterior limbs ambulatory, with numerous carpal and metacarpal bones; two aorta roots; integument consisting partly of scales; | *Reptilia*. |
| Anterior limbs volant, with the carpals and metacarpals more or less coössified and reduced in numbers; integument consisting in part of feathers; one aorta root; | *Aves*. |

Approximations between these subclasses exist at various points. Thus the Dinosaurian reptiles resemble birds in the structure of the posterior limbs and pelvis; while among birds the Saururæ approach reptiles in the structure of the manus and of the caudal vertebræ. The definitions above given are, however, not violated.

### Subclass I.—REPTILIA.

The diversities in the orders of reptiles are seen chiefly in the constitution of the posterior parts of the skull; the shoulder-girdle presents a good many varieties, and the limbs and vertebræ exhibit others.

In order to understand the homologies of the elements which make up the posterior region of the skull of reptiles generally, it is necessary to become acquainted with the skull of the primitive order of the Cotylosauria, and the most nearly allied subclass of the Batrachia, the Stegocephali. These are represented in figures. In these types the temporal fissure is crowned with an osseous roof which protects the temporal muscles. This roof contains the elements of the arches which extend from the orbit posteriorly to the suspensorium of the quadrate bone. These elements are six in number, and are named as follows, commencing with those that lie next to the parietal and the frontal bones, the posterior of each pair being mentioned first: first pair, supramastoid and postfrontal; second pair, squamosal and postorbital; third pair, quadrato-jugal and jugal (or malar). The appearance of two foramina in this roof determines the presence of two arches, a superior or postorbito-squamosal, and an inferior, or quadrato-jugal. The presence of one foramen only, results in the development of a single arch. Which of the two arches remains will depend on the position of the foramen, and the degree of excavation of the inferior edge of the temporal roof. In the Plesiosauria this arch is the quadrato-jugal; in the Lacertilia it is the postorbito-squamosal. In the Theromora it is postorbito-squamosal, but much of the quadrato-jugal adheres to its lower border, as in the Mammalia. In the Archosaurian series (with two postorbital bars) these elements are widely separated. In the Testudinata parts of both bones may be combined into one, or one only may be represented. The supramastoid bone disappears as a distinct element early in the history of the Reptilia. In the Theromora the quadrate bone grows shorter as we approach the Mammalia, and coincidentally the quadrato-jugal disappears, as for instance in the Cynodontia (Seeley).

The quadrate bone is supported on a peduncle formed by the transverse extension of the exoccipital, petrosal and opisthothic bones. The opisthotic is generally early fused with the exoccipital, but in the Ichthyopterygia and Testudinata it is distinct, and takes the place of the petrosal as a support of the quadrate in conjunction with the exoccipital. In the Pythonomorpha a bone which occupies the position of the terminal part of the opisthotic (or paroccipital, which is the older name) issues from between the exoccipital and petrosal, and supports the quadrate. Whether this is homologous with part or all of the paroccipital is an open question. For the present it is called, in this book, the paroccipital, and it is probably a distinct element from the opisthotic. In the Lacertilia it is excluded from the embrace of the petrosal and exoccipital, and is carried on their extremity, and is in contact with the quadrate. In the Serpentes, in consequence of the loss of the arches, the quadrate is borne on the extremity of this paroccipital, which generally projects freely from the cranium.

The vertebræ of Reptilia are either biconcave (amphicœlous), or flat at both extremities (amphiplatyan), or ball and socket. The latter is of two types: first, with the socket in front and the ball behind or procœlous, which is the most frequent; or second with ball in front and socket behind, or opisthocœlous. Intervertebral articulations other than those of the zygapophyses are found; as the zygosphen and zygantrum, (Serpentes, Fig. 29, p. 81), and the hyposphen and hypantrum (Dinosauri Saurischia, Fig. 22, p. 69), and some others.

In the scapular arch, a sternum, proscapula, presternum, interclavicle and clavicle may be present or absent. Scapula and coracoid are always present, and usually a precoracoid.

Twelve orders of Reptilia are known:

I. The quadrate bone immovably fixed to the adjacent elements by suture.

A. Scapular arch external to ribs; temporal region with a complex bony roof; no longitudinal postorbital bars.

A tabular and supramastoid bones, and a presternum; limbs ambulatory; vertebræ amphicœlous; (1) *Cotylosauria.*

AA. Scapular arch internal to ribs; temporal region with complex roof and no longitudinal bars.

A presternum; limbs ambulatory; (2) *Chelydosauria.*

AAA. Scapular arch internal to ribs; sternum extending below coracoids and pelvis; one postorbital bar.

No supramastoid; a paroccipital; clavicle not articulating with scapula; (3) *Testudinata.*

AAAA. Scapular arch external to ribs; one longitudinal postorbital bar (Synaptosauria).

A supramastoid and paroccipital bones; ribs two-headed on centrum; carpals and tarsals not distinct in form from metapodials; vertebræ amphicœlous; (4) *Icthyopterygia.*

A supramastoid; paroccipital not distinct; a postorbito-squamosal arch; ribs two-headed; a clavicle; obturator foramen small or none; vertebræ amphicœlous; (5) *Theromora.*

*No supramastoid; paroccipital not distinct; a quadrato-jugal arch; scapula triradiate; no clavicle; ribs one-headed; (6) *Plesiosauria.*

AAAAA. Scapular arch external to ribs; two longitudinal postorbital bars (paroccipital arch distinct). (Archosauria).

*a,* A supramastoid bone.

Ribs two-headed; a clavicle and interclavicle; acetabulum closed; no obturator foramen; ambulatory; vertebræ amphicœlous; (7) *Pelycosauria.*

*aa,* No supramastoid.

---

*Cope, Proc. Amer. Philos. Soc., 1894, identifies and describes a supra-mastoid in the plesiosaurian skull.—ED.

Ribs two-headed; interclavicle not distinct; external digits greatly elongate to support a patagium for flight; (8) *Ornithosauria.*

Ribs two-headed; no interclavicle; acetabulum open; ambulatory; (9) *Dinosauria.*

Ribs two-headed; an interclavicle; acetabulum closed; ambulatory; (10) *Loricata.*

Ribs one-headed; an interclavicle; acetabulum closed, a large obturator foramen; ambulatory; (11) *Rhynchocephalia.*

II. Quadrate bone loosely articulated to the cranium and at the proximal end only. (Streptostylica).

No distinct supramastoid, nor opisthotic; one or no postorbital bar; scapular arch external to ribs when present; ribs one-headed; (12) *Squamata.*

It appears that four orders are Paleozoic in age, one of which possibly continues into the Trias (Theromora). Four are exclusively Mesozoic, while four continue to exist.

The Theromora present the greatest resemblances to the Mammalia, while the Cotylosauria present resemblances to the Stegocephalian Batrachia with which they agree essentially in the structure of the temporal roof, in the presence of the tabular and supramastoid bones.

---

**The three plates which follow present diagrams of dorsal and lateral views of all of the orders of Reptilia except the Chelydosauria. The bones are indicated by a uniform system of abbreviations.—Ed.**

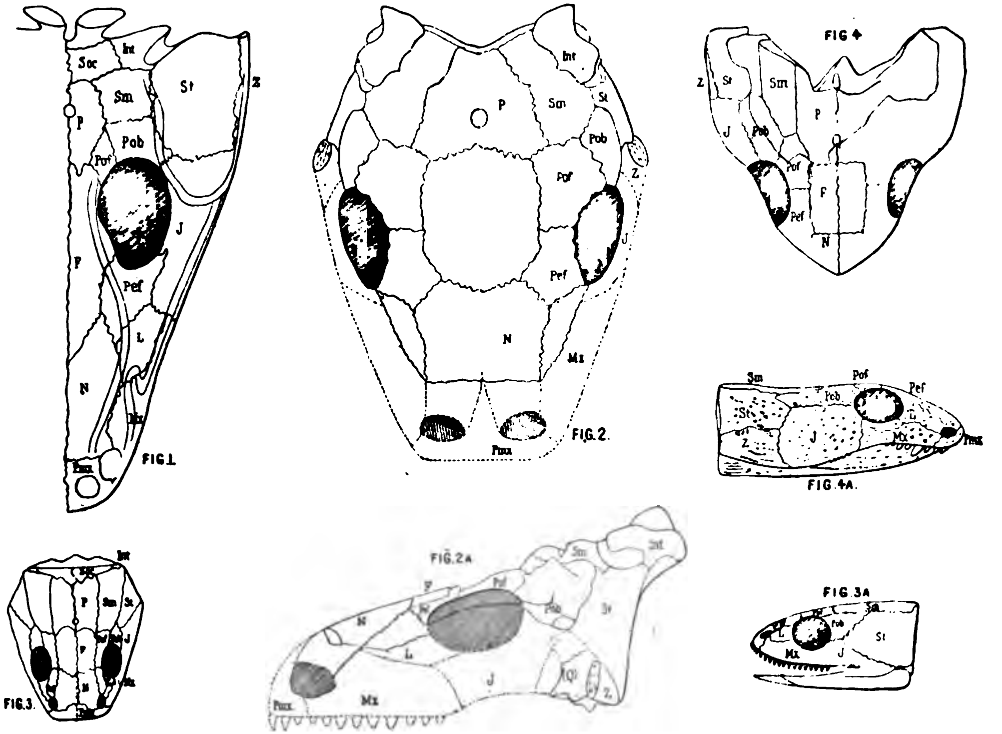


PLATE I.—1. *Mastodonsaurus* Jaeger; 2. *Chilonyx* Cope; 3. *Pariotichus* Cope (Cotylosauria); 4. *Pantylus* Cope.

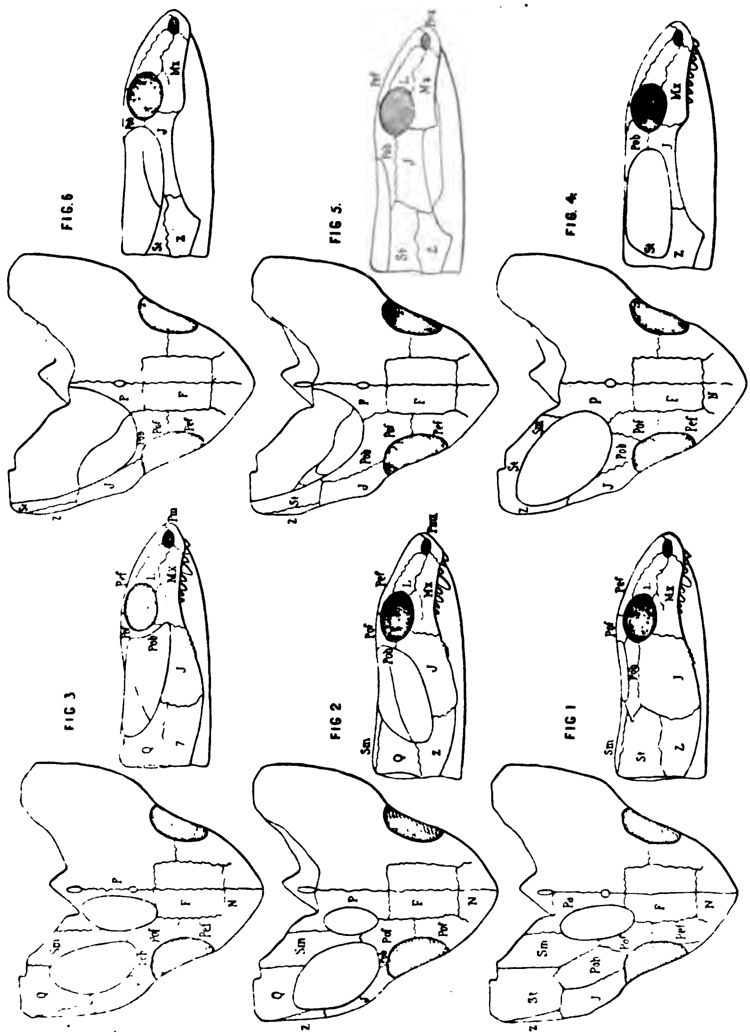


PLATE II.— 1. *Ichthyopterygia*; 2. *Dinosauria*; 3. *Loricata*; 4. *Plesiosauria*; 5-6. *Testudinata*.

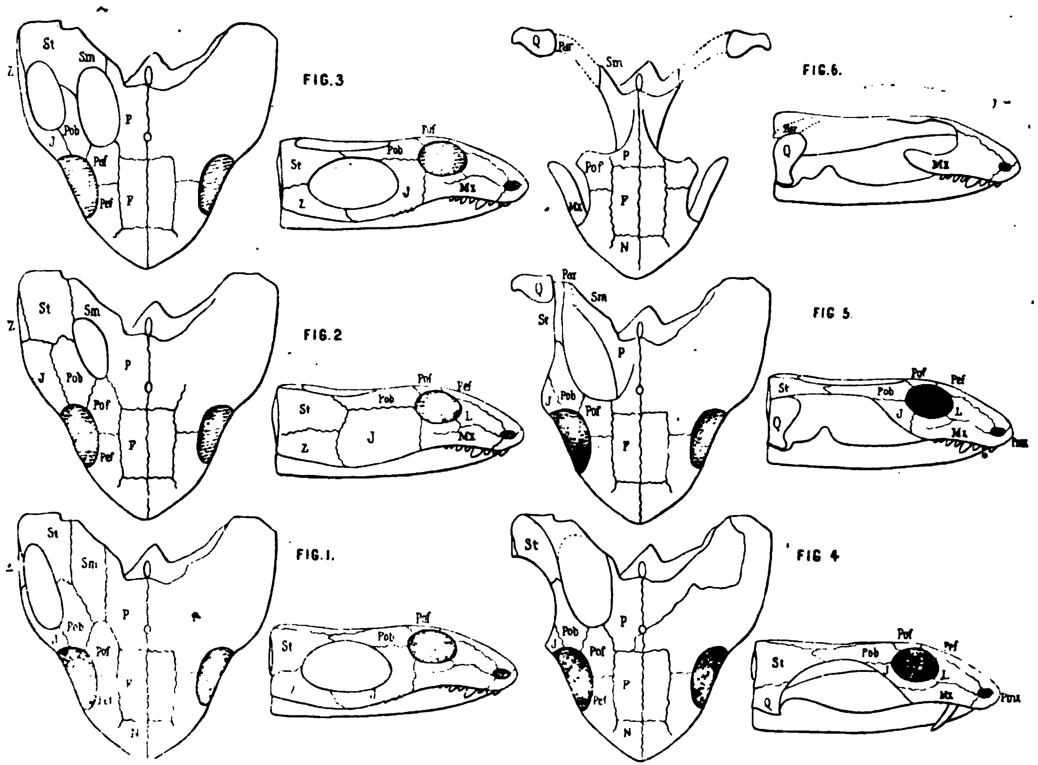
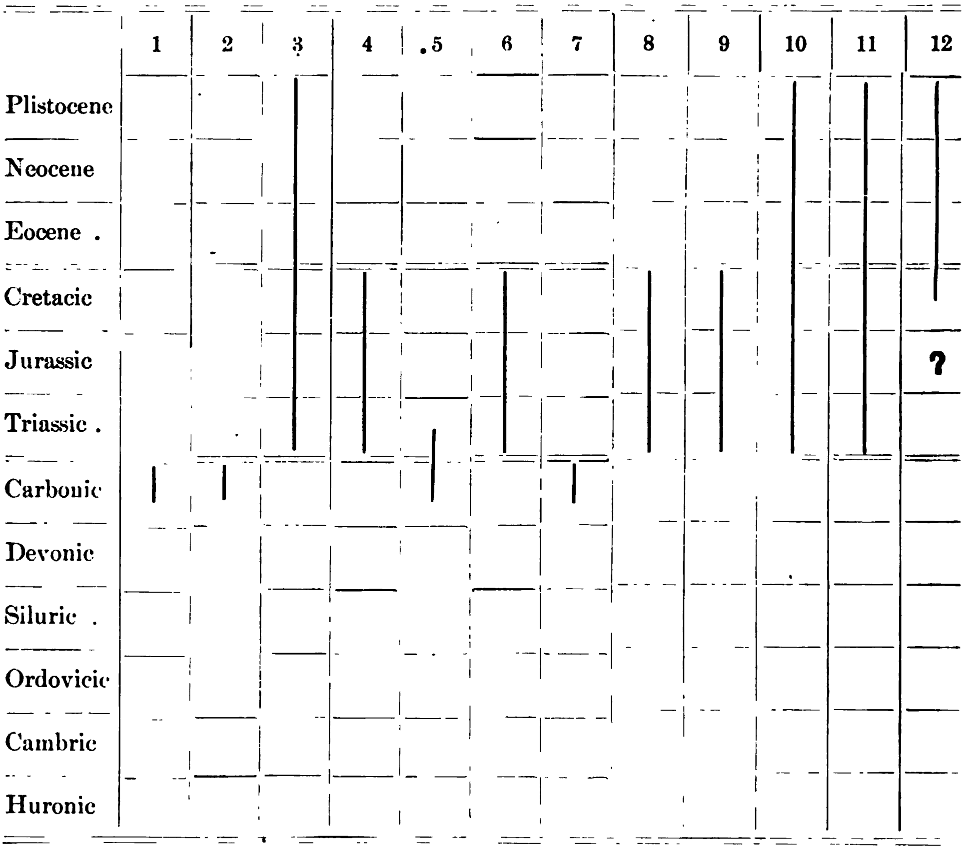


**Plate** III.—1. *Pelycosauria*; 2. *Pseudosuchia* (Loricata); 3. *Rhynchocephalia*; 4. *Anomodontia* (Theromora); 5. *Lacertilia*; 6. *Ophidia*

The time-histories of the orders of reptiles are represented in the accompanying table:



The order Cotylosauria includes reptiles with amphicœlous vertebræ and of terrestrial habits. There are four families, the Pariasauridæ, of robust form varying from the size of an alligator to that of a cat, from the Permian beds of South Africa and North America; the Diadectidæ (Fig. 17), with hyposphen-hypantrum vertebral articulation, and teeth with robust, molariform crowns, transverse to the jaws, from

North America and Europe; the Pariotichidæ, with several rows of teeth in the jaws, from North America; and the Elginiidæ with very thin ossifications and light structure, from the Trias of Scotland. This order is probably ancestral to all

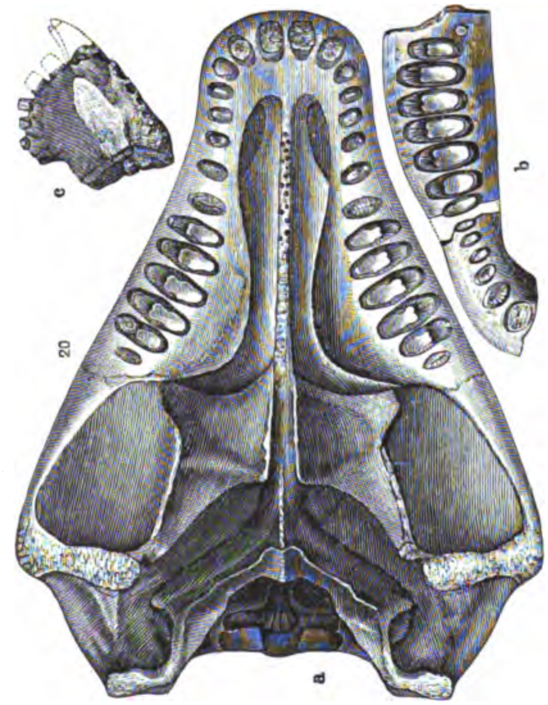


**FIG. 17.**—*Empedias molaris* Cope; inferior view of skull, one-third natural size. A Cotylosaurian from the Permian of Texas.

other orders of Reptilia. The oldest reptile known is the Isodectes punctulatus Cope from the Coal Measures of Ohio. The South African forms Gorgonops and Procolophum probably belong here, and are supposed to be types of distinct families.

The CHELYDOSAURIA is an order of limited extent, with present knowledge, as it includes but one family, the Otocœlidæ, from the Permian formation of North America. These reptiles possessed a carapace of transverse osseous arches which extended across the back from side to side in close contact. The anterior part of the scapular arch below resembles the corresponding part of the plastron of a tortoise. The temporal roof is excavated posteriorly for the auricular meatus. The order is probably ancestral to the Testudinata and the Pseudosuchia.

The order TESTUDINATA presents four subordinal modifications, as follows:

I. No descending processes of the parietal bones.

Vertebræ and ribs free and separated from a bony exoskeleton; no descending processes of the parietals; *Athecæ.*

II. A carapace and plastron, and descending process of parietals.

*a*, Sacral and caudal ribs articulating with neural arches only.

Neck bending in vertical plane, last cervical articulating with first dorsal by zygapophyses only; pelvis not anchylosed; marginal bones wanting or rudimental; *Trionychoidea.*

*aa*, Sacral and caudal ribs articulating with body of vertebræ only.

As the last; but marginal bones present and connected with ribs, and last cervical and last dorsal vertebræ articulating by bodies; pelvis not anchylosed to plastron; *Cryptodira.*

Neck bending in horizontal plane, the last cervical and first dorsal vertebræ articu-

lating by bodies; pelvis anchylosed to
carapace and plastron; marginal bones
present and connected with ribs; *Pleurodira.*

The *Athecæ* includes the single family of the Dermochelydæ.

The *Trionychoidea* includes only the Trionychidæ.

The *Cryptodira* embraces the Cheloniidæ, Testudinidæ (Fig. 18), Cinosternidæ, Dermatemydidæ, Chelydridæ, Baënidæ, and Adocidæ.

The *Pleurodira* includes the the Pleurosternidæ, Sternotheridæ, Pelomedusidæ, Plesiochelydidæ, Chelydidæ, and Carettochelydidæ.

The earlier tortoises are intermediate in character be-

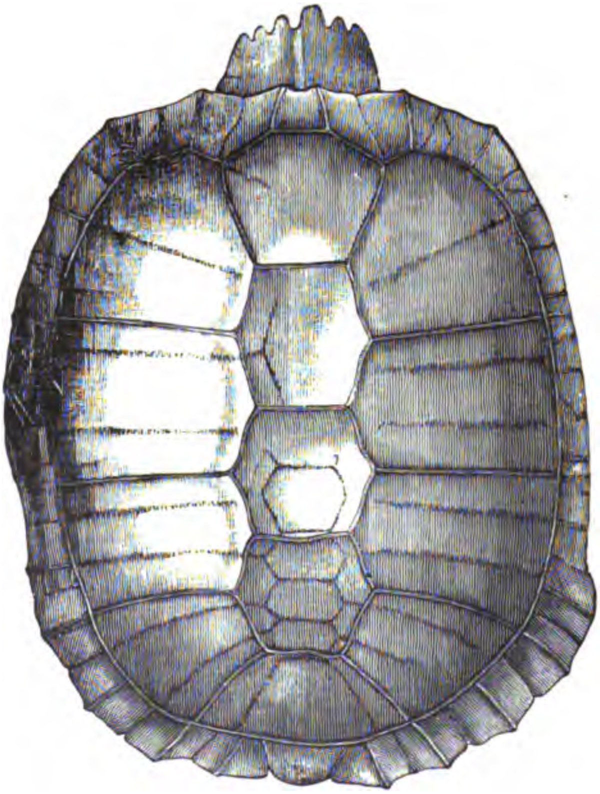


FIG. 18.—*Testudo laticuneus* Cope; carapace, from above, one-fourth natural size. From the White River Neocene bed of Nebraska.

tween the Cryptodira and Pleurodira, and they have continued side by side to the present day. The Pleurodira are, however, now confined to the Southern Hemisphere. The Trionychoidea first appear in the Cretacic, and continue as the so-called soft-shell turtles of fresh water. The Atheca first appear in the Eocene, and were then and still are marine in their habits; but one species now exists, the "leather-back turtle."

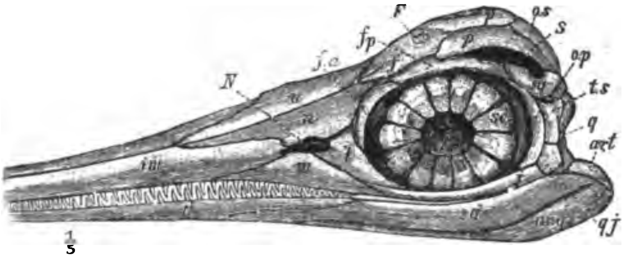


**Fig. 19.**—***Ichthyosaurus tenuirostis*** **Conyb.; one-sixth natural size. From the Lias of Würtemburg. From Doederlein.**

The order ICHTHYOPTERYGIA embraces the families of Ichthyosauridæ (Fig. 19) and Mixosauridæ. The Mixosauridæ have the bones of the forearm and leg distinguished by their form from those of the carpus and tarsus, and they thus approach more nearly other reptiles. They are the oldest family, having inhabited European waters during the period of the Trias. In the Ichthyosauridæ all the bones of the limbs have the same form, except the humerus and femur. They continued until the close of the Cretacic. They were the especially marine Reptilia, having the shape and habits of the Cetacea. They reached the length of twenty-five feet during the Cretacic period. Their remains have been found in all parts of the world except Africa, but they were more numerous in the oceans now covered by Europe than elsewhere. Some of the forms had but few (Muræenosaurus) and others (Baptanodon) no teeth. The typical genera had numerous teeth grooved at the base. The vertebræ are short and biconcave.

The order THEROMORA includes five suborders, and perhaps others. They differ as follows:

I. Palate imperforate; interior nares posterior.

Teeth molariform; one occipital condyle; *Placodonta.*

II. Palate perforated anteriorly for internal nares.

*a*, Occipital condyle single.

Dentition complete, teeth compressed; *Theriodonta.*
Teeth absent or reduced to one pair above; *Anomodonta.*

*aa*, Occipital condyles two.

Teeth compressed; *Cynodonta.*
Teeth molariform; *Gomphodonta.*

Some of the suborders are imperfectly known. In all of them it is probable, and in many of them certain, that the supratemporal bone extends forward above the malar nearly to the orbit, and that it sometimes includes, with the latter, a foramen (Cynodonta), thus simulating two postorbital bars. In the Gomphodonta and Cynodonta the two occipital condyles correspond with those of Mammals, and the quadrate is so abbreviated as to render it highly probable that these groups are the ancestors of the Mammalia. With the extreme shortening of the quadrate the quadrato-jugal bone disappears, and the supratemporal becomes the zygomatic part of the squamosal of the Mammal. In these suborders and in many of the Theriodonta, the canine teeth are greatly enlarged. The families are as follows:

PLACODONTA : Placodontidæ, Trias of Europe.

THERIODONTA: ?Proterosauridæ, Permian of Europe; Rhynchosauridæ, Trias of Europe and India; Lycosauridæ, Permo-Trias of South Africa and Europe.

ANOMODONTA; Dicynodontidæ (Fig. 20), Permo-Trias of South Africa, Asia and Europe.

CYNODONTA : Galesauridæ, Permo-Trias of South Africa.

GOMPHODONTA : Tritylodontidæ, Permo-Trias of South Africa.

In all of the suborders of the Permian of South Africa where the parts are known, the obturator foramen and the coracoid bone are small.

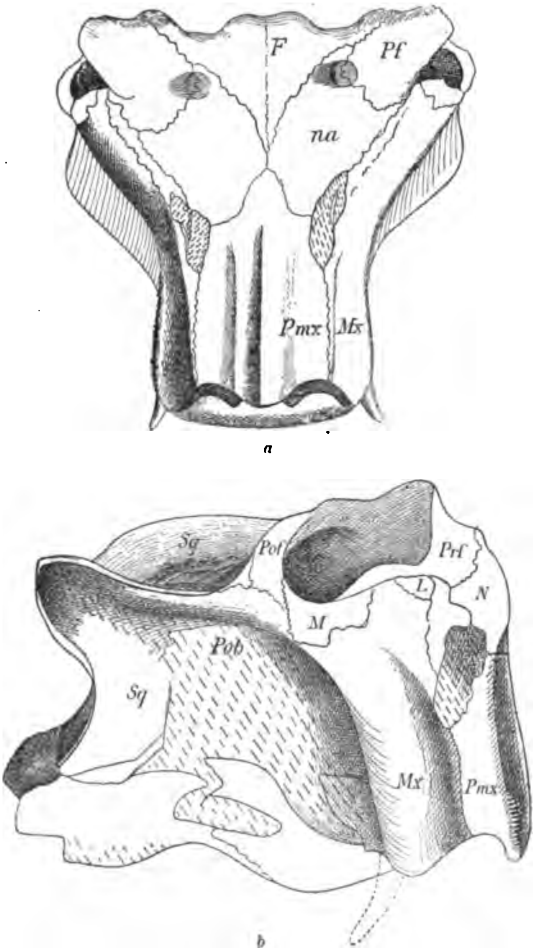


**Fig. 20.**—*Lystrosaurus frontosus* Cope; an Anomodont from South Africa, one-third natural size.

The Plesiosauria embraces the following families: Plesiosauridæ, Nothosauridæ, and Lariosauridæ. The last two families are only known from the Triassic of Europe. The Plesiosauridæ range from the Jurassic to the Cretacic, inclusive, and include many species. They are all adapted for aquatic life, and were sometimes formed like the Cetacea; but others had very long necks, which could extend the head to great depths or reach the surface when the body was sunk. Some of the species reached a length of forty or fifty feet. Their remains have been found in North and South America, Europe, and New Zealand.

The Pelycosauria includes the families of the Bolosauridæ and Clepsydropidæ, which were carnivorous and abundantly provided with teeth. They have been found in the Permian of South Africa, North America and Europe.

Two families enter the ORNITHOSAURIA, viz., the Pteranodontidæ and the Pterodactylidæ. The last-named family is furnished with teeth, while the first-named includes species which have a toothless beak like that of a bird. The Pterodactylidæ range from the Trias to the Cretacic inclusive. The earlier forms had a long tail, and these continued through the Jurassic (Fig. 21). Some of the later forms had an edentulous beak in front of the toothless portion. The true Pterodactyles had a much abbreviated tail and a long neck.

The Ornithosauri were the flying order of reptiles, comparing with the other orders much as bats compare with other orders of Mammalia.

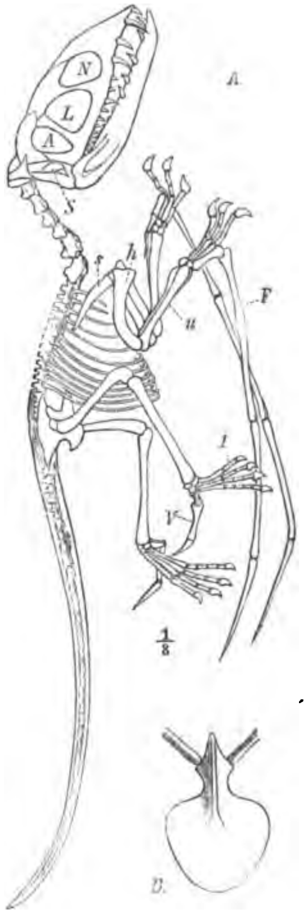


FIG. 21.—*Dimorphoda macronyx* Ow. from the English Trias. *B*, sternum. From Owen.

The Dinosauria embrace two suborders, as follows:

| | |
|---|---|
| Pubic elements directed downwards; | *Saurischia.* |
| Pubic elements directed backwards; | *Orthopoda.* |

The Saurischia were mostly of carnivorous habits, while the Orthopoda were herbivorous. Both suborders commence in the Trias, and close with the end of the Postcretacic. To the Saurischia belong two families, the Cetiosauridæ and the Megalosauridæ, the former supposed to be herbivorous, the latter carnivorous. The former have robust inferior pelvic bones, and teeth with spoon-shaped crowns. The latter have long, slender pubis and ischium, and sharp, knife-shaped teeth.

To the Cetiosauridæ belong the largest known Vertebrata with ambulatory legs; the *Camarasaurus supremus* Cope measuring seventy feet in length, and the *Amphicœlias fragilissimus* Cope being considerably larger. These creatures had the dorsal vertebræ hollow, and probably penetrated in life by branches from the lungs, while the tail vertebræ and limb bones are solid. The former served as floats and the latter as anchors as they walked on the sea bottom. This family is only known from the Jurassic of Europe and North America (Fig. 22). The Megalosauridæ ranged throughout all Mesozoic time. Some of the species were quite small, and others were gigantic, being the most dangerous carnivorous animals that ever existed. Many of them were of kangaroo-like form, and in some of them the vertebræ were mere hollow shells. In most of them the limb bones were hollow.

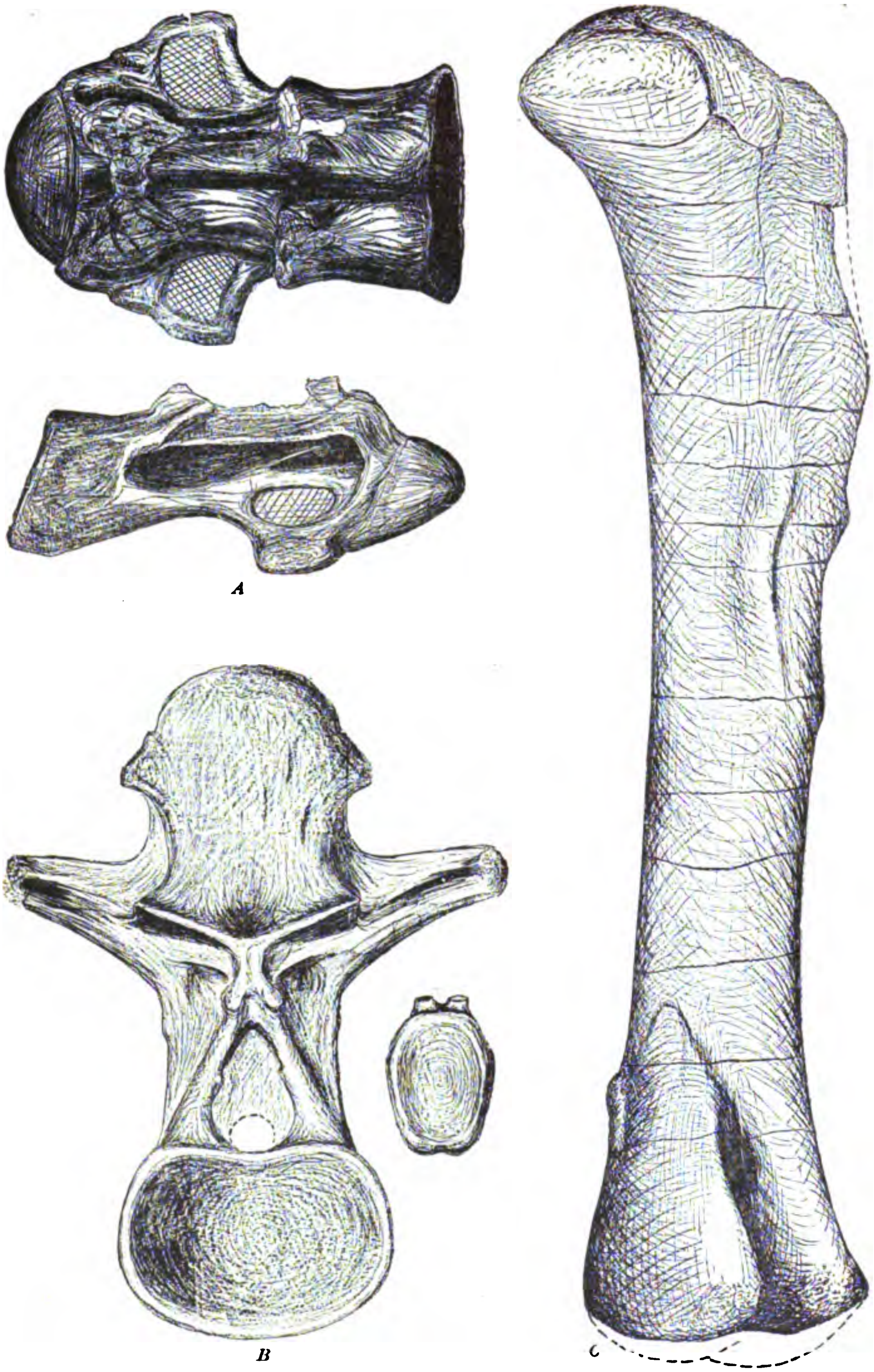


FIG. 22.—Cetiosauridæ; *A*, *Camarasaurus supremus* Cope; cervical vertebra, from above and side, one-tenth natural size; *B*, do., dorsal vertebra, from behind, one-tenth natural size; *C*, *Amphicœlias altus* Cope; femur, from behind, one-tenth natural size.

The Orthopoda includes the Scelidosauridæ, Hypsirhophidæ, Agathaumidæ, Camptosauridæ, Iguanodontidæ and Hadrosauridæ, all supposed to have been of herbivorous habits. Representatives of these families have been found in both Europe and North America, excepting the Scelidosauridæ, the members of which are so far only known from Europe. They all include large forms, but the most gigantic are members of the last four families. These had an additional bone, the predental, which formed a toothless extremity of the lower jaw, while the Agathaumidæ had a corresponding toothless bone in front formed of the premaxillary. In all the families except the Agathaumidæ the successional teeth appear on the inner side of the base of the functional teeth, as in lizards. In the Agathaumidæ they appeared under the middle of the base, as in crocodiles. In all except Hadrosauridæ one row was in functional use at a time; but in the Hadrosauridæ two or three rows were used at once, Some of the species of the latter had as many as 2,000 teeth arranged in four magazines, one in each jaw (Fig. 23). The Agathaumidæ mostly had formidable horns on the head, at the middle of the nose and over the eyes. *Agathaumas sylvestre* Cope reached a length of forty feet, and had the legs of sub-equal length. Many of the Hadrosauridæ were of kangaroo-like proportions.

The Dinosauria include the great land reptiles of the Mesozoic system. The order embraces no species adapted for flight, and none adapted for a life in which movement was made by paddles or limbs modified for swimming. The order includes the largest land animals that have ever lived, and their remains have been found in all continents except the Australian.

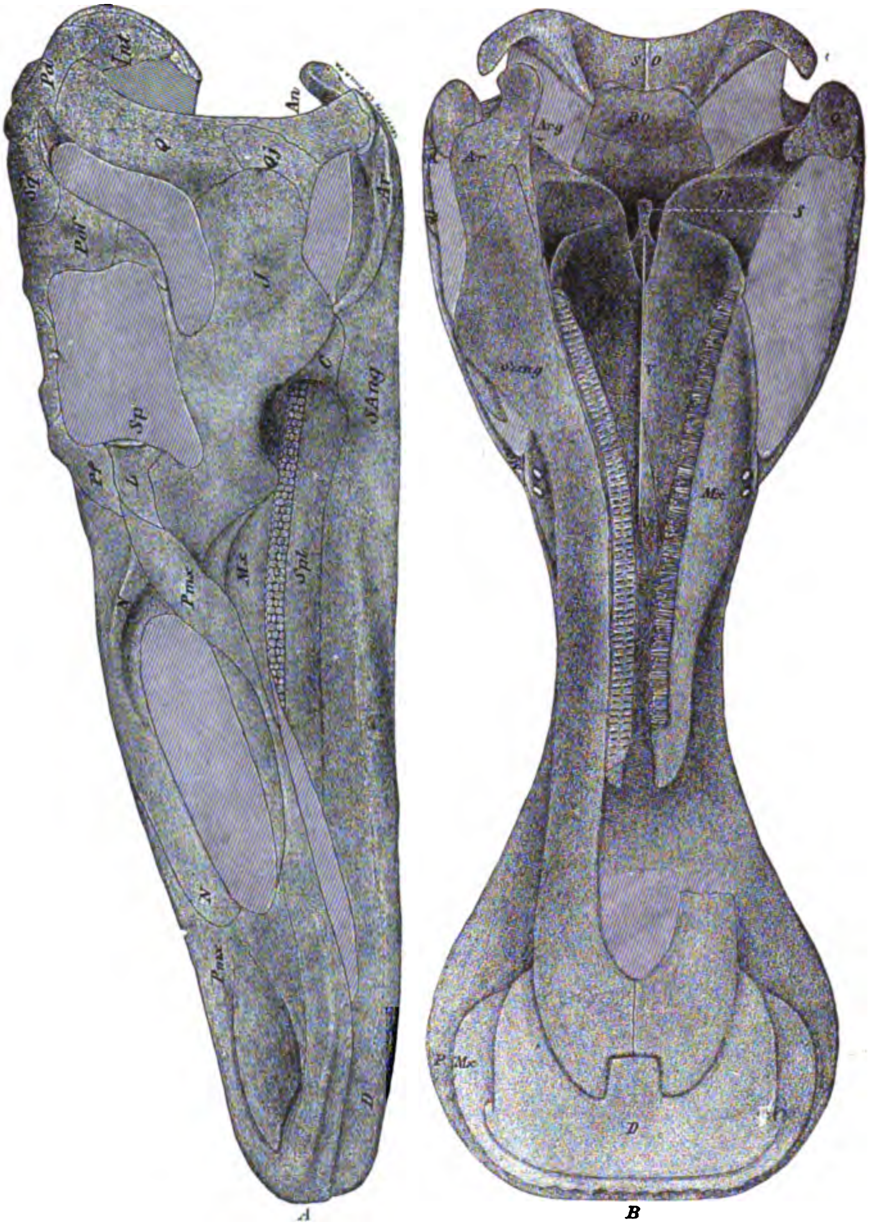


**FIG. 23.**—*Diclonius mirabilis* Leidy; skull one-seventh natural size. From Cope. *A*, from side; *B*, from below. From the Laramie beds of Dakota.

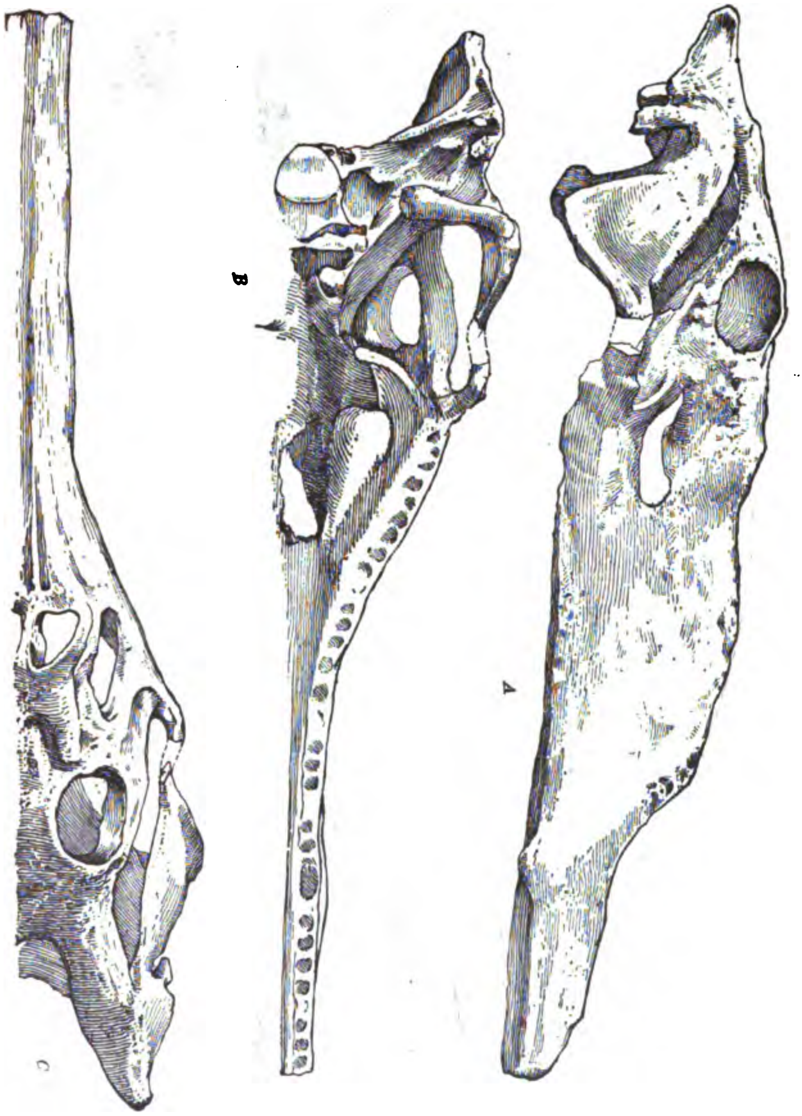


FIG. 21.—*Belodon buceros* Cope; skull, one-fourth natural size. From the Trias of the Rocky Mountains. *A*, the side; *B*, below; *C*, above. Original.

The LORICATA includes three suborders, as follows:

| | |
|---|---|
| Posterior nostrils opening in front of palate; nasals very short; premaxillary very large; external nostrils posterior, nasals short; | *Parasuchia.* |
| Nasal bones very long, separating the small premaxillaries; external nostrils anterior; | *Pseudosuchia.* |
| Nareal canal underroofed to behind larynx; no clavicle; pubis excluded from acetabulum; external nostrils anterior; | *Eusuchia.* |

The Parasuchia and Pseudosuchia are restricted to the Trias of both continents. The most important family of the Parasuchia is the Belodontidæ (Fig. 24). The Pseudosuchia include the Aëtosauridæ, the members of which were completely incased in an armor of bony plates. To the Eusuchia belong the true crocodiles. They commence in the Jurassic with the Teleosauridæ and Goniopholididæ, which are followed in the Cretacic by the Crocodilidæ (Fig. 25) and Gavialidæ, which still exist.

The RHYNCHOCEPHALIA include two suborders:

| | |
|---|---|
| Vertebræ amphicœlous; axis undivided; | *Sphenodontina.* |
| Vertebræ amphiplatyan; dentatum of axis separate; | *Choristodera.* |

To the Sphenodontina belong the Protorosauridæ and Paleohatteriidæ, from the European Trias, the Homœosauridæ, from the European Jurassic, and the Sphenodontidæ, which are represented by one species now living in New Zealand. They are all of terrestrial habit, and of small or medium size. The only family of the Choristodera is that of the Champsosauridæ, which is found in the Postcretacic of North America and the Eocene of Europe. The species were aquatic, and reached the size of some of the modern caymans. The dentine is inflected at the base of the teeth, and the limbs were paddle-like. This order furnishes the starting point for the great Archosaurian series.

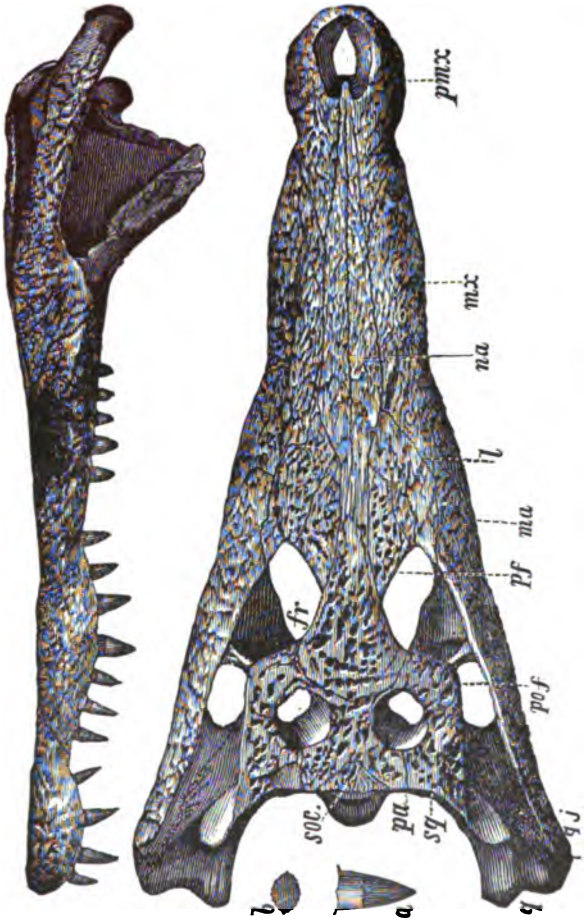


FIG. 25.—*Crocodilus acer* Cope; skull, one-third natural size. From the Eocene of Utah. Original.

The SQUAMATA is an extended group which exists under the following three subordinal forms:

Quadrate supported usually by exoccipital; paroccipital bone on end of exoccipital peduncle; frontal and parietal little decurved; brain-case open in front; roots of teeth dentinal; *Lacertilia.*

Quadrate supported by paroccipital, which is deeply embraced by the exoccipital and petrosal; frontal and parietal little decurved, brain-case open in front; roots of teeth osseous; *Pythonomorpha.*

Quadrate supported by paroccipital which articulates with the brain-case directly; frontal and parietal decurved to sphenoid, closing brain-case in front; teeth rootless; *Serpentes.*

In general the Lacertilia have two pairs of limbs, and the corresponding scapular and pelvic arches, but there are many exceptions. The Pythonomorpha known have two pairs of paddles in which all of the elements are distinguishable, and scapular and pelvic arches. In the Serpentes limbs and the supporting arches are wanting, excepting rudiments of the posterior in a few forms.

The three suborders of Squamata first appear in the Cretacic system. The Lacertilia and Ophidia still exist, but the Pythonomorpha do not survive Mesozoic time.

The LACERTILIA embrace the following superfamilies:

I. Petrosal not produced anterior to semicircular canal, and not articulating above with the parietal; olfactory lobes not under-arched; hemipenis mostly calyculate.

Digits, including metapodials, in opposing groups of two and three about a centrale carpi and tarsi respectively; tongue papillose, extremity sheathed; no clavicles; 2 *Rhiptoglossa.*

Digits all directed forwards; clavicles proximally simple; interclavicle anchor-shaped; tongue papillose, not sheathed; 3 *Pachyglossa.*

II. Petrosal produced anterior to semicircular canal, not articulating above with the edge of the parietal.

*a*, Clavicle proximally expanded; olfactory lobe underarched by frontal.

Tongue papillose or smooth; hemipenis calyculate; 4 *Nyctisaura.*

*aa*, Clavicle proximally simple; olfactory lobes underarched by frontal.

Vertebræ amphicœlous; no supratemporal arch; tongue papillose; 5 *Urolatoidea.*

Vertebræ procœlous; a supratemporal arch; interclavicle anchor-shaped; tongue smooth; hemipenis flounced; 6 *Thecaglossa.*

Vertebræ procœlous, no supratemporal arch; interclavicle simple; tongue papillose; hemipenis flounced; 7 *Helodermatoidea.*

*aaa*, Clavicle simple proximally, olfactory lobes not underarched by frontal.

Interclavicle cruciform; tongue papillose; hemipenis flounced; 8 *Diploglossa.*

*aaaa*, Clavicle proximally expanded; olfactory lobes not underarched.

Vertebræ procœlous; tongue scaly; hemipenis flounced or plicate; 9 *Leptoglossa.*

III. Petrosal produced anterior to the anterior semicircular canal, articulating above with the border of the parietal.

*a*, Olfactory lobes underarched by frontals, no supratemporals, nor ceratohyals; cervical and caudal intercentra coössified with the middle of the centra.

Palatine and pterygoid foramina; an epipterygoid; tongue papillose; 10 *Annielloidea.*

No palative nor pterygoid formina; no epipterygoid; 11 *Annulati.*

A group which does not enter any of the above superfamilies is the Dolichosauria (1.) On account of ignorance of its essential characters, its position cannot be definitely fixed, but it differs from other Lacertilia in the large number of cervical vertebræ, which is more than nine, according to Owen. Teeth pleurodont.

The families of these superfamilies are the following:

*Dolichosauria;* Dolichosauriidæ.
*Rhiptoglossa;* Chamæleonidæ.
*Pachyglossa;* Agamidæ, Iguanidæ (Fig. 26.)
*Nycisauria;* Eublepharidæ, Geckonidæ.
*Uroplatoidea;* Uroplatidæ.
*Thecaglossa;* Varanidæ.
*Helodermatoidea;* Helodermidæ.
*Diploglossa;* Zonuridæ, Pygopodidæ, Anguidæ, Xenosauridæ.
*Leptoglossa;* Xantusiidæ, Teiidæ, Lacertidæ, Gerrhosauridæ, Scincidæ, Acontiidæ, Anelytropidæ.
*Annielloidea;* Aniellidæ.
*Annulati;* Chirotidæ, Amphisbænidæ, Trogonophidæ.

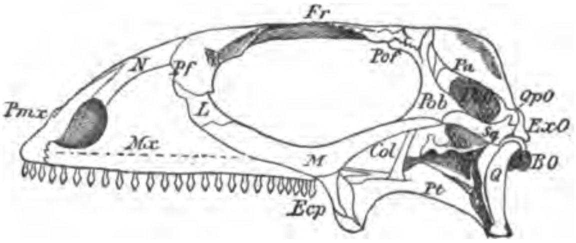
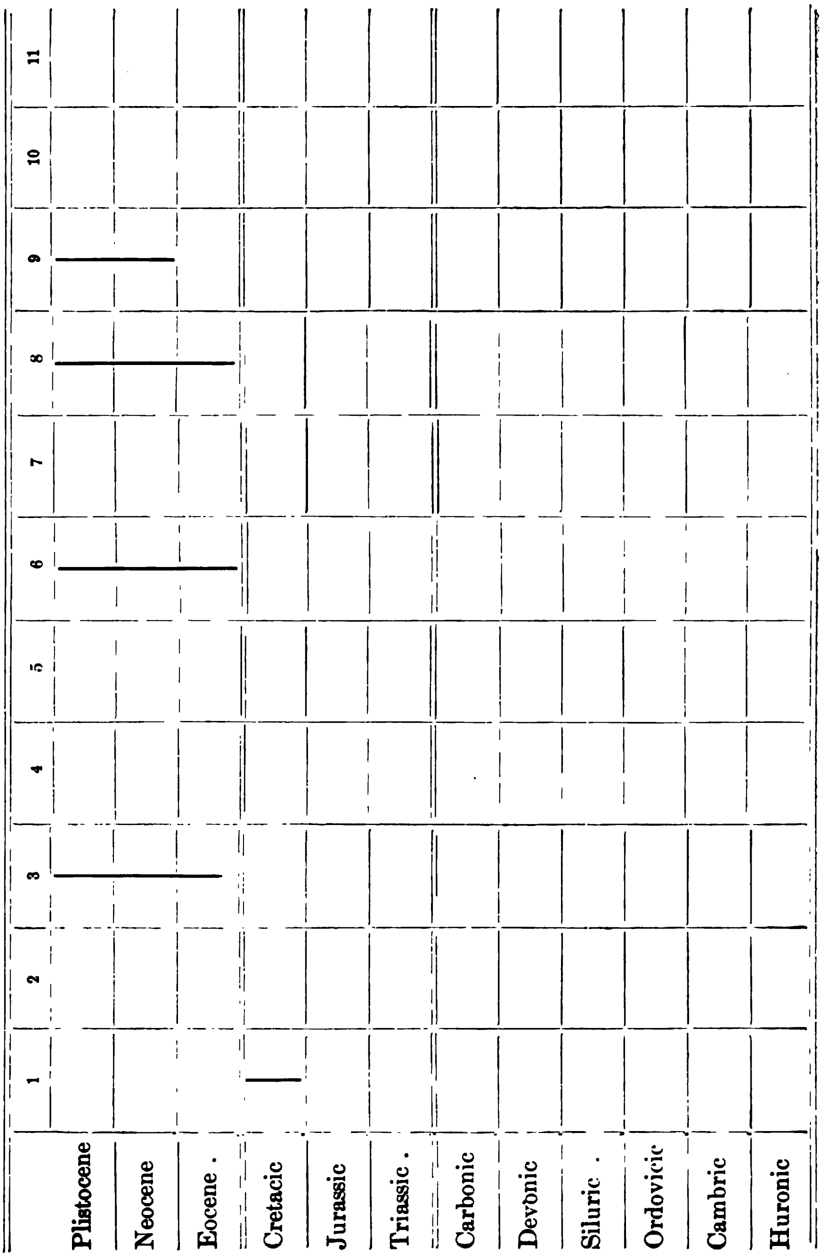


**FIG. 26.—Skull of *Iguana tuberculata* Linn; external side view, natural size.**

The recent forms of the Lacertilia are much more numerous than the known fossil forms.

The geologic history of the Lacertilia is as follows: Column No. 1 represents the Dolichosauria.



The Dolichosauria are only known from European formations. Some of the species are snake-like in form. Acrodonta are best known from the same region, but one species is known from the American Eocene. It may belong to the Rhiptoglossa. The extinct Iguania and Leptoglossa are all European as far as known, while Diploglossa are known from both continents.

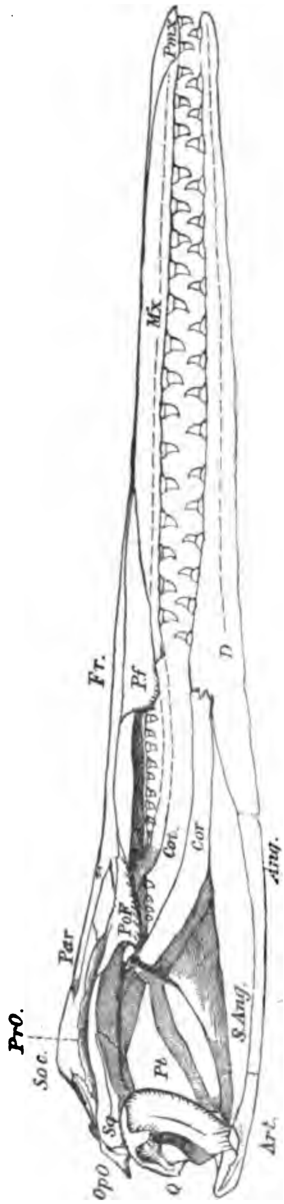


**FIG. 27.**—*Clidastes propython* Cope; skull one-half natural size. From the Upper Cretacic of Alabama.

The PYTHONOMORPHA (Fig. 27) include two families, the Mosasauridæ and the Plioplatecarpidæ. The Mosasauridæ were the predominant type of sea-saurians during the Cretacic period in North America, and they were common in Europe and in New Zealand, and some species have been found in Brazil. The Plioplatecarpidæ are only known from the Upper Cretacic in Europe. Some of the species of Mosasaurus and Liodon reached a length of fifty feet. Their limbs were short, inflexible paddles, and the pelvic bones were very slender and feeble.

The OPHIDIA include the following superfamilies:

A. Supratemporal intercalated in the cranial walls. (*Angiostomata.*)
  *a*, No ectopterygoid; palatines bounding choanæ posteriorly; ethmoturbinal forming part of roof of mouth; rudiments of a pelvis. (*Scolecophidia.*)

Maxillary bone fixed to prefrontal and premaxillary; a pelvis; (1) *Catodonta* (blind snakes).

Maxillary bone vertical and free from all others; no pelvis; (2) *Epanodonta* (blind snakes).

*aa*, An ectopterygoid; palatines not bounding choanæ posteriorly.

Maxillary bone free, horizontal; (3) *Tortricina*.

AA. Supratemporal attached scale-like to cranial walls, produced freely posteriorly; ectopterygoid present. (*Eurystomata.*)

Maxillary bone horizontal, not articulated with the prefrontal by a ginglymus, hence not erectile; (4) *Colubroidea*.

Maxillary bone vertical, not reaching premaxillary, articulating with the prefrontal by a ginglymus, and to the ectopterygoid without imbrication, and bearing a perforated tooth; (5) *Solenoglypha* (vipers and pitvipers).

By far the greater number of snakes belong to the superfamily Colubroidea. These fall into four primary tribes which differ as follows:

I. No grooved or channeled teeth.

Rudimental posterior extremities; *Peropoda*.

No rudiments of extremities; *Aglyphodonta*.

II. Some teeth grooved or channeled.

One or more grooved teeth on the posterior part of the maxillary bone; *Opisthoglypha*.

A channeled or perforate tooth at the anterior end of the maxillary bone; *Proteroglypha*.

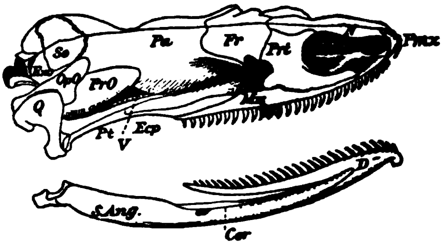


FIG. 28.—*Xenopeltis unicolor* Reinwt, from Siam; skull, natural size. Original. (Asinea.)

The Peropoda are believed to be the most primitive snakes, from which the other divisions have been derived. The line to the Proteroglypha and Solenoglypha is an ascending one, while that to the Tortricina and Catodonta is a descending one.

The families embraced by these superfamilies are as follows:

*Catodonta ;* Stenostomidæ.

*Epanodonta ;* Typhlopidæ.

*Tortricina ;* Tortricidæ, Uropeltidæ.

*Colubroidea ;* (Peropoda) Pythonidæ, Boidæ (Fig. 29), Charinidæ, Ungualiidæ; (Aglyphodonta), Xenopeltidæ (Fig. 28), Acrochordidæ, Nothopidæ, Colubridæ ; (Opisthoglypha) Dipsadidæ ; (Proteroglypha), Elopidæ, Najidæ, Dendraspididæ, Hydrophidæ.

*Solenoglypha ;* Causidæ, Atractaspididæ, Viperidæ, Crotalidæ.

The paleontology of the snakes is very imperfectly known. The oldest known genus, Symoliopsis Sauv., from the Neocomian of France, may be either one of the Catodonta or Epanodonta. The oldest forms of Asinea (harmless snakes) are Pythonidæ and Boidæ ; they occur in both continents.

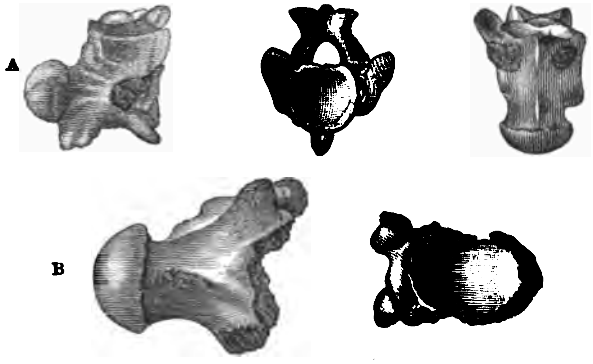
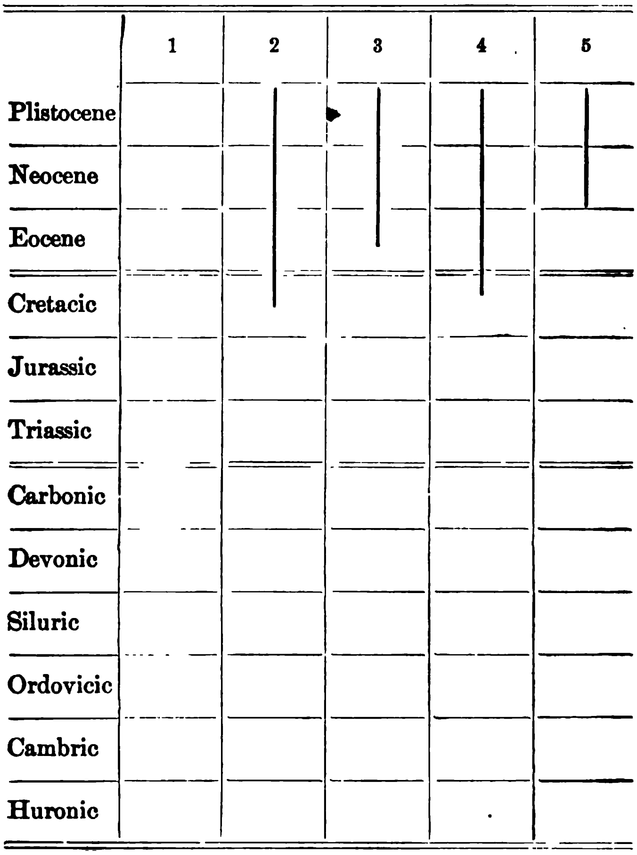


FIG. 29.—A, *Palæophis littoralis* Cope; B, *P. halidanus* Cope; vertebræ Both from the Eocene of New Jersey. Cope.

The largest are the species of Paleophis Owen, which occur in the Eocene of New Jersey and England; they equaled the largest existing pythons in dimensions (Fig. 29). The venomous snakes appear in the Neocene in both Europe and North America.

The geological distribution of the superfamilies of snakes is as follows:



## Subclass II.—AVES.

There are two superorders of the birds as follows:

Metacarpal and carpal bones all distinct, the digits with ungues; caudal vertebræ numerous, unmodified; clavicles united; pelvic elements distinct; teeth present; *Saururæ.*

**FIG. 30.**—***Archæopteryx lithographica*** **Wagn. From Middle Oölite of Bavaria much reduced. From Dames.**

Metacarpal and carpal bones reduced in number, coössified; ungues wanting or single; caudal vertebræ reduced in number, the terminal areas usually coössified; *Eurhipiduræ*

The SAURURÆ includes but one order, which is defined as follows:

Vertebræ biconcave; feathers arranged in one series on each side of the caudal vertebræ; teeth present; *Ornithopappi.*

To this order but one family belongs, viz., the Archæopterygidæ.

This family is represented by one genus, Archæopteryx from the Oölite (Middle Jurassic) of Solenhofen, Bavaria. It was furnished with long feathers on the wings, adapting it for flight, and the long lizard-like tail had a row of long feathers on each side of it. It is the oldest known type of birds, and is an important one as showing the near connection of birds with reptiles. (Fig. 30.)

The EURHIPIDURÆ include four or five tribes which differ as follows:

Ischium free from ilium posteriorly;* palate dromæognathous (*i. e.*, maxillopalatines articulating with vomer which is between them, palatines not articulating directly with sphenoid rostrum); no teeth; (1) *Ratitæ.*

Ischium free from ilium posteriorly; palate? dromægnathous; teeth; (2) *Odontolcæ.*

Ischium free from ilium posteriorly; palate not dromæognathous(?); teeth; (3) *Odontotormæ.*

Ischium coössified with ilium posteriorly; palate not dromæognathous; feathers

---

*With some apparent exceptions.

| | |
|---|---|
| distributed in areas, those of the wings much differentiated; | (4) *Euornithes.* |
| Ischium coössified with ilium posteriorly; no teeth; feathers universally distributed and not differentiated on wings; | (5) *Impennes.* |

The Ratitæ are the ostriches and their allies; the Odontolcæ and Odontotormæ are toothed birds; the Impennes are the penguins, and the Euornithes are the remaining, or typical birds. The geological distribution of these tribes is as follows:

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Plistocene . . . | ┃ | | | ┃ | ┃ |
| Neocene . . . . | ┃ | | | ┃ | ┃ |
| Eocene . . . . | ┃ | | | ┃ | ┃ |
| Cretacic . . . . | | ┃ | ┃ | | |
| Jurassic . . . . | | | | | |
| Triassic . . . . | | | | | |
| Paleozoic . . . . | | | | | |

The Ratitæ includes the following orders:

| | |
|---|---|
| Sternum without keel; clavicles; wings rudimental; | *Struthiones.* |
| Sternum without keel; no clavicles; wings rudimental; | *Apteryges.* |
| Sternum with keel; clavicles; wings rudimental; | *Gastornithes.* |
| Sternum with keel; clavicles; wings functional; | *Crypturi.* |

The families belonging to these orders are the following:

*Struthiones;* Struthionidæ (ostriches), Rheidæ, Casuariidæ, Dromæidæ, Dinornithidæ (Fig. 31), Æpiornithidæ.
*Apteryges;* Apterygidæ (kiwis).
*Gastornithes;* Gastornithidæ.
*Crypturi;* Crypturidæ (tinamus).

Of the above families the Struthionidæ are remarkable in having the pubes forming a ventral symphysis. The Rheidæ are equally remarkable in having a ventral symphysis of the ischia. The geological range of these orders is as follows:

| | **Struthiones** | **Apteryges** | **Gastornithes** | **Crypturi** |
|---|---|---|---|---|
| Plistocene . . . | │ | │ | | |
| Neocene . . . . | │ | | | |
| Eocene . . . . | | | │ | |
| Cretacic . . . . | | | | |
| Jurassic . . . . | | | | |
| Triassic . . . . | | | | |
| Carbonic . . . . | | | | |
| Devonic . . . . | | | | |
| Siluric . . . . . | | | | |
| Ordovicic . . . | | | | |
| Cambric . . . . | | | | |
| Huronic . . . . | | | | |

Extinct Struthiones are known from all the great regions of the Old World, but none from the New. The extinct Apteryges come from the Australian realm only. The Gastornithes are known from the Eocenes of both Europe and North America. Gastornis has persistent sutures of the skull, and a tooth-like process on the upper jaw. *G. edwardsii* was nine feet high. The species of Dinornis (Fig. 31) from the Plistocene of New Zealand were all of large size, some of them reaching twelve feet in height. One species is known from Australia.

FIG. 31.—*Dinornis parvus* Owen. From Plistocene of New Zealand. From Owen. *Il*, ilium; *is*, ischium; *pp*, pubis; *st*, sternum; *B*, tarsometatarsus.

The tribe ODONTOLCÆ includes but one order:

Teeth in a groove; sternum without keel;
wings rudimental; pelvic bones free
posteriorly; vertebræ saddle-shaped; *Dromæopappi.*

The DROMÆOPAPPI has but one family, the Hesperornithidæ, which have been only found so far in the Upper

Cretacic of Middle North America. They have many of the characters of the divers (order Cecomorphæ).

To the ODONTOTORMÆ one order only is referred. It is thus characterized:

Teeth in sockets; sternum keeled; wings well developed; ischium and pubis free posteriorly; vertebræ biconcave; *Pteropappi.*

The family of the Ichthyornithidæ is the only one known to belong to the PTEROPAPPI. Its members are known from the Upper Cretacic of North America and the Lower Cretacic of England.

The EUORNITHES include numerous suborders, which are defined as follows:

1. Maxillopalatines united across the middle of the palate. (*Desmognathæ*).

A. Four toes directed forwards (pamprodactylous).

Toes webbed; no basipterygoids; (1) *Steganopodes.*

Toes free; vomer unossified; no basipterygoid processes; (2) *Colioidei.*

AA. Three toes directed forwards.*

Short basipterygoid processes; toes generally webbed; præcocial; (3) *Chenomorphæ.*

No basipterygoid processes; bill and legs slender; toes generally free; altricial; (4) *Herodii.*

Bill and claws hooked; toes free; vertebræ saddle-shaped; altricial; (5) *Accipitres.*

Bill hooked; toes free; vertebræ opisthocœlous; rostrum movably ar-

---

* Except Cuculidæ and Rhamphastidæ, which are zygodactylous.

ticulated with skull; basipterygoids; (6) *Heterospondyli.*

Toes free; vertebræ saddle-shaped; rostrum fixed; (7) *Coccygomorphæ.*

AAA. First and fourth toes directed backwards (zygodactylous).

Rostrum freely articulated with the skull; vertebræ opisthocœlous; (8) *Psittaci.*

AAAA. First and second toes directed backwards (heterodactylous).

Basipterygoids present; heteropelmous; (9) *Trogonoidei.*

II. Maxillopalatines not united across the palate; vomer narrowed and acute in front. (*Schizognathæ.*)

A. Toes three forwards (anisodactylous).

Schizorhinal; toes webbed; (10) *Cecomorphæ.*

Toes free; legs long; feathers with aftershaft; præcoces; (11) *Grallæ.*

No basipterygoids; lachrymal bones coössified with rostrum; toes free; (12) *Opisthocomi.*

Toes free; hallux rudimental; (13) *Gallinæ.*

Toes free; hallux well developed; two carotid arteries; (14) *Pullastræ.*

Toes free; hallux well developed; one carotid artery; basipterygoids; (15) *Micropodioidei.**

AA. First and fourth toes directed backward (zygodactylous).

---

* Family Trochilidæ.

No cæca coli; no interclavicle; one carotid artery; (16) *Picoidei.*

III. Maxillopalatines not united on median line; vomer single, truncate, and excavated in front. (*Ægithognathæ.*)

A. Toes three in front (anisodactylous).

Toes free; hallux well developed; tarsometatarsus with five tendinous canals; basipterygoids wanting or rudimental; sternum with two notches; no cæca coli; one carotid artery; (17) *Passeres.*

AA. Four toes directed forwards (pamprodactylous).

Toes free; no basipterygoids; sternum entire posteriorly; tensor patigii brevis muscle attached to a tendon which extends to the manus; no cæcacoli; (15) *Micropodioidei.**

The cormorants, pelicans, and boobies of the Steganopodes appear in the Eocene. The Eocene representatives of the Chenomorphæ are primitive flamingoes, the true ducks and geese not appearing before the Neocene. The Eocene Accipitres are Falconidæ, the owls not appearing before the Neocene. The kingfishers are the earliest representatives of the Coccygomorphæ, appearing in the Eocene; the remaining families are not known prior to the Neocene. The Phasianidæ of the Gallinæ appear in the Middle Eocene. It is thus evident that the majority of the families of the Euornithes are not known prior to the beginning of the Neocene system.

The time distribution of the Euornithes is as follows, as far as known:

---

* Family Cypselidæ.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plistocene | │ | | │ | │ | │ | | │ | │ | │ | │ | │ | | │ | │ | │ | │ | │ |
| Neocene | │ | | │ | │ | │ | | │ | │ | │ | │ | │ | | │ | │ | │ | │ | │ |
| Eocene . | │ | | │ | | │ | | │ | | | | | | │ | | | | |
| Cretacic | | | | | | | | | | | | | | | | | |
| Jurassic | | | | | | | | | | | | | | | | | |
| Triassic | | | | | | | | | | | | | | | | | |
| Carbonic | | | | | | | | | | | | | | | | | |
| Devonic | | | | | | | | | | | | | | | | | |
| Siluric . | | | | | | | | | | | | | | | | | |
| Ordovicic | | | | | | | | | | | | | | | | | |
| Cambric | | | | | | | | | | | | | | | | | |
| Huronic | | | | | | | | | | | | | | | | | |

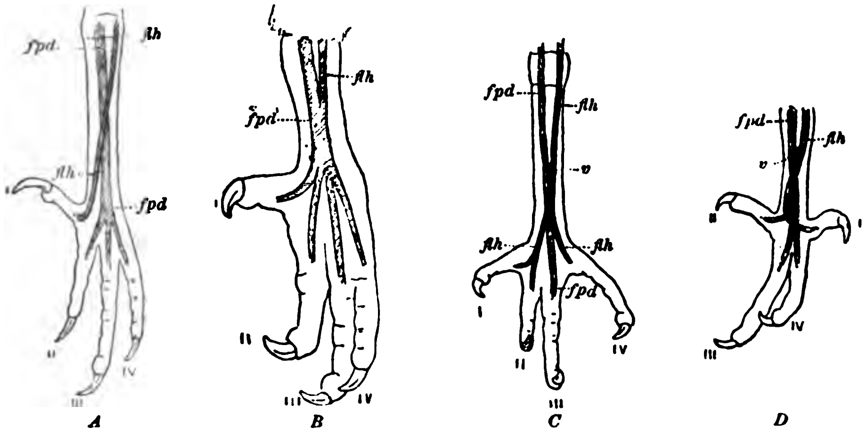


FIG. 32.—Diagrams exhibiting the more important modes of distribution of the deep plantar tendons in Euornithes. *A*, nomopelmous (schizopelmous); *B*, synpelmous (desmopelmous); *C*, antipelmous; *D*, heteropelmous; *flh*, flexor longus hallucis; *fpd*, flexor perforans digitorum *v*, vinculum. *I* to *IV*, 1st to 4th toes. (After Stejneger).

The digits of birds are arranged in several different orders. The usual type with three toes forwards and one backwards is termed anisodactylous; that with the first and fourth backwards and second and third forwards, is syndactylous. When the first and second are directed backwards and the third and fourth forwards the arrangement is termed heterodactylous; and when all four are directed forwards the foot is said to be pamprodactylous. The flexor tendons of the toes are arranged differently in these different digital arrangements, although not always identically in the same. The arrangement usual in the anisodactylous foot is the schizopelmous system, where the flexors of the digits 2–3–4 have a common stem, while that of digit 1 is distinct. In some anisodactylous feet, however, all the flexors or tendons are more or less fused ; this is the desmopelmous system ; it occurs also in many zygodactylous feet. In another type of zygodactylous foot (that of the Picoidei) we have the antipelmous arrangement. Here all the tendons are fused excepting that of third, which is distinct. Finally in the heterodactylous foot we have the heteropelmous

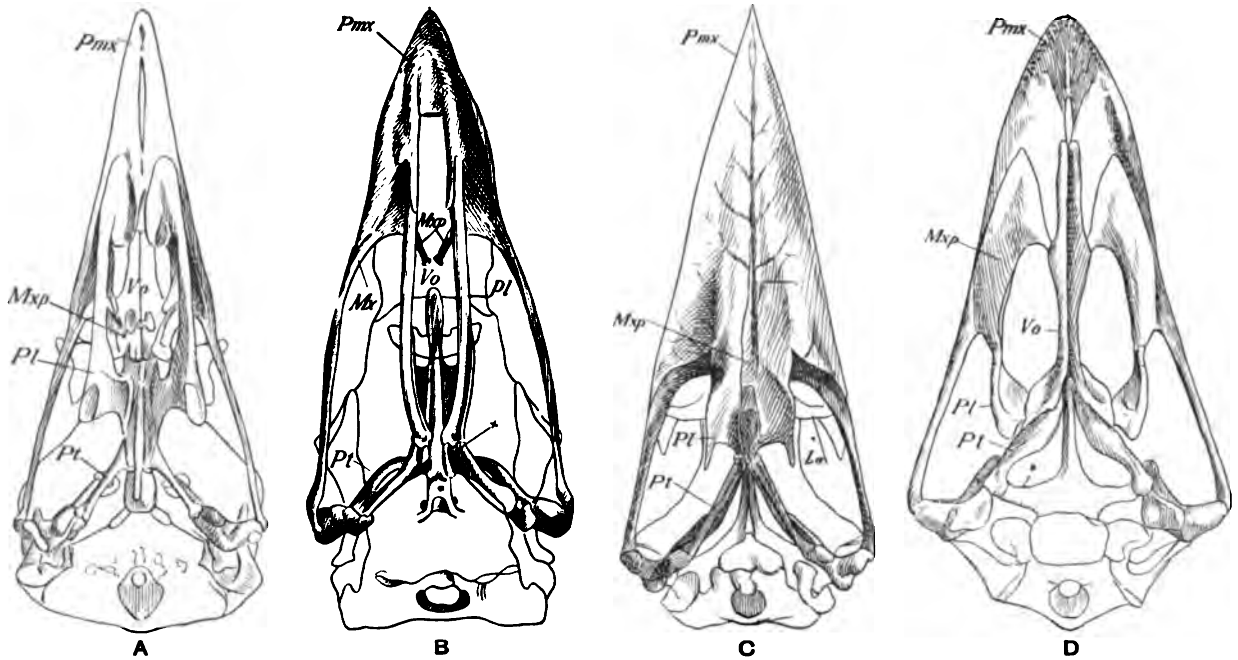


FIG. 33. Illustrations of the types of palatal structure of birds. A, ægithognathus (Corvus corax); B, schizognathus (Tetrao urogallus); C, desmognathus (Dacelo gigantea); D, dromæognathus (Dromæus novæ hollandiæ). La, lachrymal; Mx. maxillary; Mxp, maxillo-palatines; Pl. palatine; Pmx. premaxillary; Pt, pterygoid; Vo, vomer: x (in B) and * (in D) basi-sphenoidal processes. (After Huxley).

tendons, where the first and second form a common stem, and the third and fourth a common stem, following the arrangement of the digits. (Fig. 32).

The palatal structure must be consulted in attempting the discrimination of the orders of birds. There are four types of structure, as follows: First, the dromæognathous palate (Fig. 33 D) has the anterior roof continuous and formed of the fused maxillopalatines and vomer. In this case, also, the vomer and pterygoid bones exclude the palatine from contact with the presphenoid, by intervening between the two. In the desmognathous palate (Fig. 33 C) the maxillopalatines join each other on the middle line, excluding the vomer, which is free and above them or aborted. Both palatines and pterygoids reach the presphenoid bone at its basipterygoid processes. In the schizognathous palate (Fig. 33 B) the maxillopalatines do not meet on the middle line, and the vomer terminates in a free acute apex above, and more or less posterior to them. The fourth type (the ægithognathous, Fig. 33 A) is a modification of the schizognathous, differing only in the form of the vomer. The anterior extremity of the latter is flattened, often expanding and notched or excavated on the anterior margin.

The families of the EUORNITHES are as follows:

*Steganopodes;* Phætonidæ, Fregatidæ, Pelecanidæ, Sulidæ, Phalacrocoracidæ, Plotidæ.

*Colioidei;* Coliidæ.

*Chenomorphæ;* Palamedeidæ, Anatidæ, Phœnicopteridæ.

*Herodii;* Ibididæ, Ciconiidæ, Balænicipitidæ, Ardeidæ.

*Accipitres;* Cathartidæ, Falconidæ, Pandionidæ, Strigidæ.

*Heterospondyli;* Steatornithidæ.

*Coccygomorphæ;* Cuculidæ, Coraciidæ, Alcedinidæ, Upupidæ, Musophagidæ, Todidæ, Momotidæ, Bucerotidæ, Rhamphastidæ, Caprimulgidæ, Bucconidæ, Indicatoridæ.

*Psittaci ;* Psittacidæ.

*Trogonoidei ;* Trogonidæ.

*Cecomorphæ ;* Colymbidæ, Heliornithidæ, Alcidæ, Laridæ, Procellariidæ.

*Grallæ ;* Chionidæ, Thinocoridæ, Glareolidæ, Dromadidæ, Charadriidæ, Otididæ, Eurypygiidæ, Rhinochetidæ, Cariamidæ, Psophiidæ, Gruidæ, Rallidæ.

*Opisthocomi ;* Opisthocomidæ.

*Gallinæ ;* Tetraonidæ, Phasianidæ.

*Pullastræ ;* Cracidæ, Megapodiidæ, Pteroclidæ, Divididæ, Columbidæ.

*Micropodioidei ;* Cypselidæ, Trochilidæ.

*Picoideæ ;* Picidæ, Yngidæ.

*Passeres.* This order is divided into five superfamilies, as follows:

I. Tensor patagii brevis picarian ; *Menuroidei.*

II. Tensor patagii brevis passerine.

A. Syrinx mesomyodian.

Tendons of flexor muscles of foot desmopelmous ; *Eurylæmoidei.*

Tendons of foot schizopelmous; syrinx bronchiotrachial ; *Tyrannoidei.*

Tendons of foot schizopelmous; syrinz trachial ; *Formicaroidei.*

AA. Syrinx acromyoctian.

Tendons of foot schizopelmous ; *Passeroidei.*

The families of these superfamilies are the following :

*Menuroidei ;* Menuridæ, Atrichornithidæ.

*Eurylæmoidei ;* Eurylæmidæ.

*Tyrannoidei ;* Xenicidæ, Philepittidæ, Pittidæ, Tyrannidæ, Cotingidæ, Phytotomidæ.

*Formicaroidei ;* Conopophagidæ, Pteroptochidæ, Formicariidæ.

*Passeroidei ;* Alaudidæ, Motacillidæ, Timaliidæ, Liotrichidæ, Muscicapidæ, Turdidæ, Cinclidæ, Troglodytidæ, Chamæidæ, Hirundinidæ, Artamidæ, Laniidæ, Paridæ, Paradisiidæ, Corvidæ, Sturnidæ, Meliphagidæ, Nectariniidæ, Certhiidæ, Ploceidæ, Tanagridæ, Icteridæ, Fringillidæ.

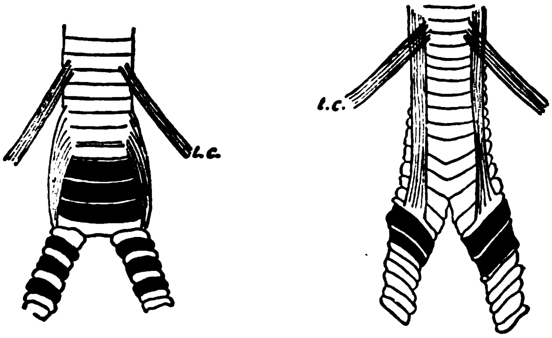


FIG. 34.—Diagrams of a tracheal and a bronchial syrinx. *t.c*, trachelo-clavicular muscle. (After Newton.)

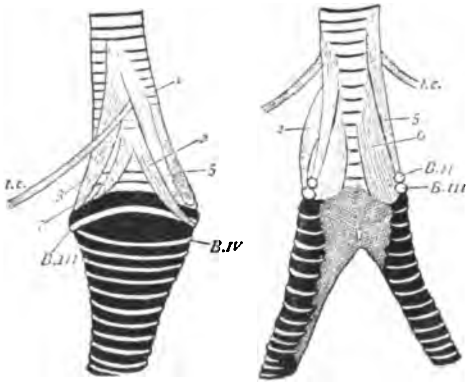


FIG. 35—Lateral and dorsal views of the acromyodian syrinx of the raven (Corvus corax), *B*, *II*, *III*, *IV*, second, third and fourth bronchial rings. 1, m. tracheo-bronchalis ventralis ; 2, m. tracheo-bronchialis obliques ; 3 and 4, m. tracheo-bronchialis dorsalis longus et brevis ; 5, m, syringeus ventralis ; 6, m. syringeus ventralis-lateralis; 7, m. syringeus dorsalis. (After Newton.)

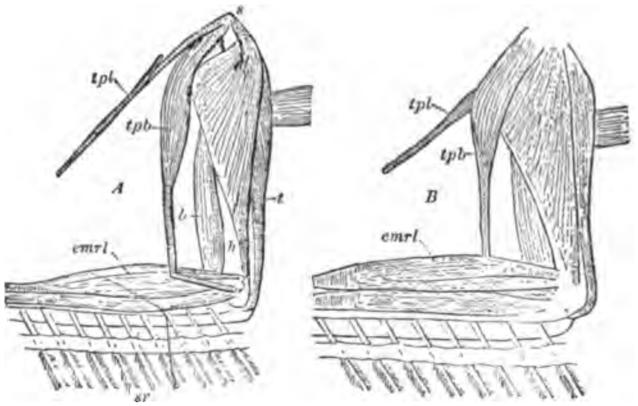


**Fig. 36.**—Diagrams of the elbow muscles of Icterus (*A*), showing the passerine type and Nenina(*B*)., showing the picarian type. *b*, biceps; *emrl*, extensor meticarpi radialis longus; *h*, humerus; *s*, shoulder; *sr*, secondary remiges: *t*, triceps; *tpb*, tensor patagii brevis; *tpl*, tensor patagii longus. (After Newton.)

To the Impennes but one order belongs. This is the Ptilopteri:

Ilium not anchylosed with sacrum; bones of wing not foldable on each other; metacarpals not separated; hallux directed forwards; feathers scale-like; vertebræ opisthocœlous; *Ptilopteri.*

The Ptilopteri includes the recent family of Aptenodytidæ or penguins. They first appear in the Upper Eocene of New Zealand. No species, living or extinct, have been found in the Northern Hemisphere.

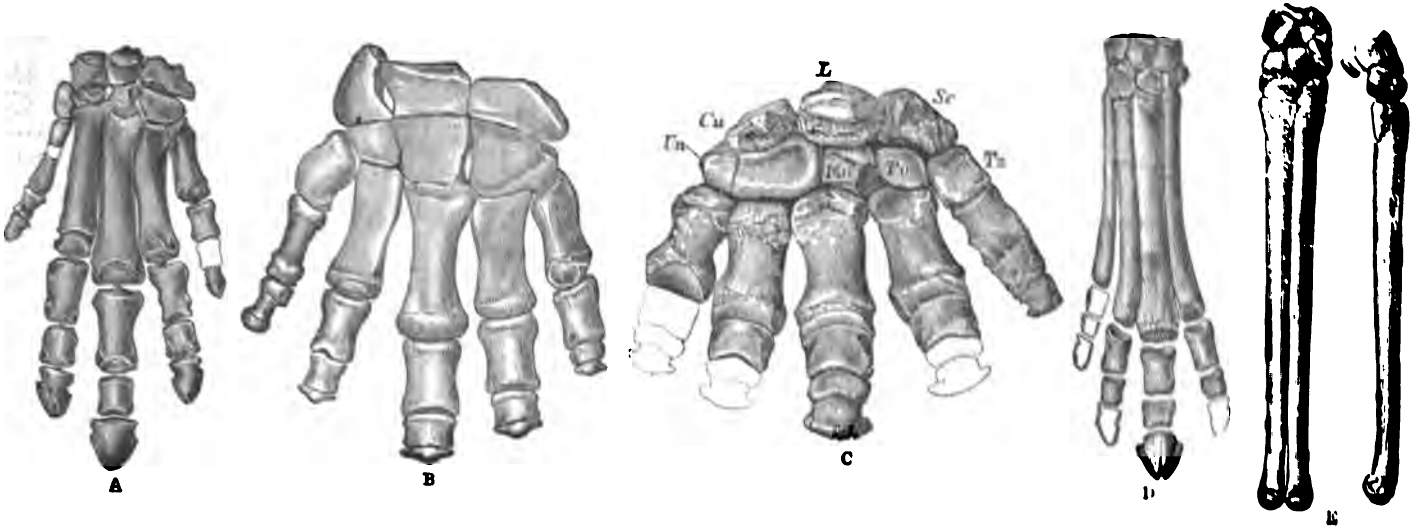


FIG. 38.—Types of carpal structure of Ungulata, A, taxeopodous of Phenacodus primævus Cope; B, proboscidian of Elephas africanus Linn.; C, amblypodous of Coryphodon elephantopus Cope; D, diplarthrous (perissodactyl) of Hyracotherium venticolum Cope; E, diparthrous (artiodactyl) of Poebrotherium labiatum Cope. In A and B digit I is at the left side, in C, D and E (so far as represented) at the right side of the figure.

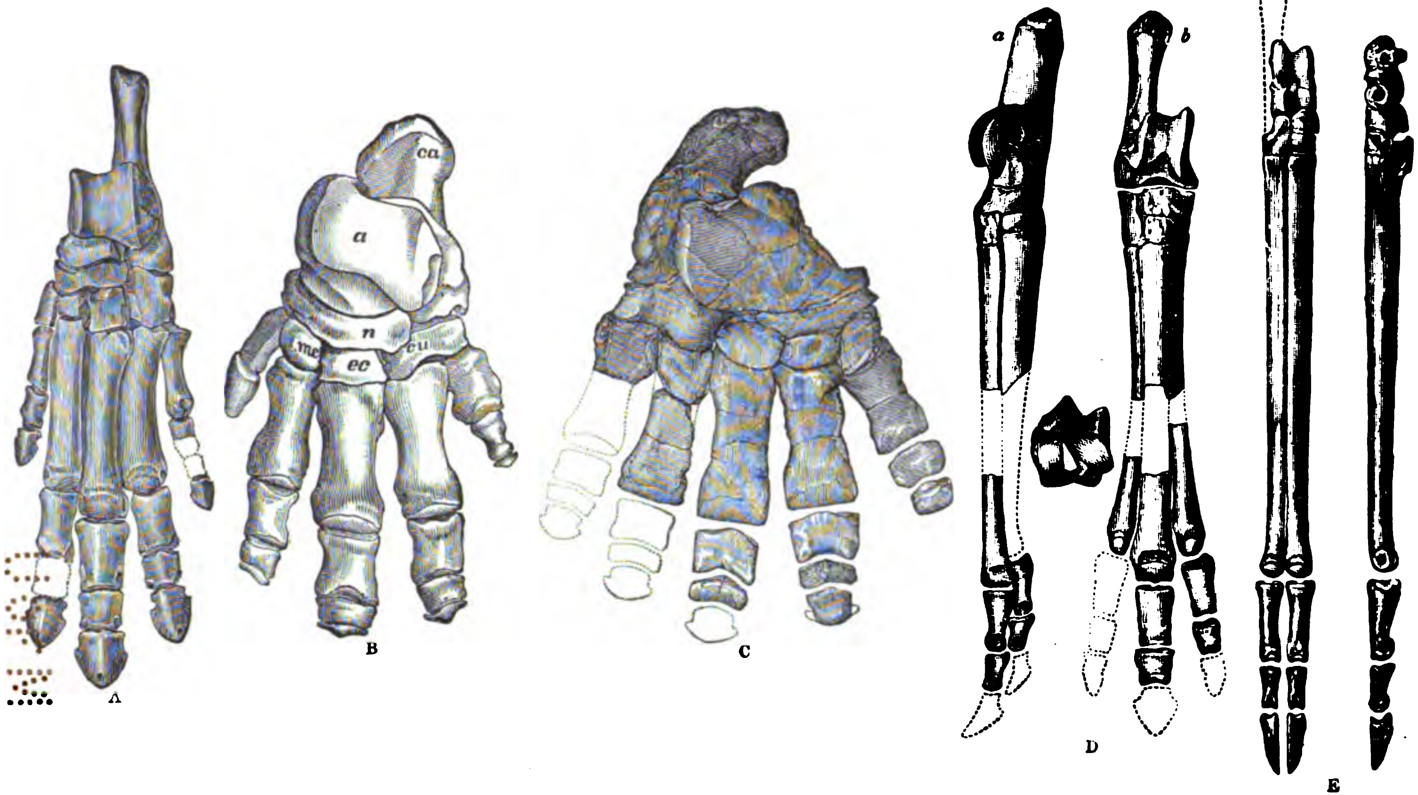


FIG. 39.—Types of ungulate tarsi—*A*, taxeopodous of *Phenacodus primævus* Cope; *B*, proboscidian of *Elephas africanus* Linn.; *C*, amblypodous of *Coryphodon elephantopus* Cope; *D*, diplarthrous (perissodactyl) of *Hyracotherium venticolum* Cope; *E*, diplarthrous (artiodactyl) of *Poebrotherium labiatum* Cope. In *A* and *B* the digits number from the left; in *C*, *D* and *E* from the right of the figure.

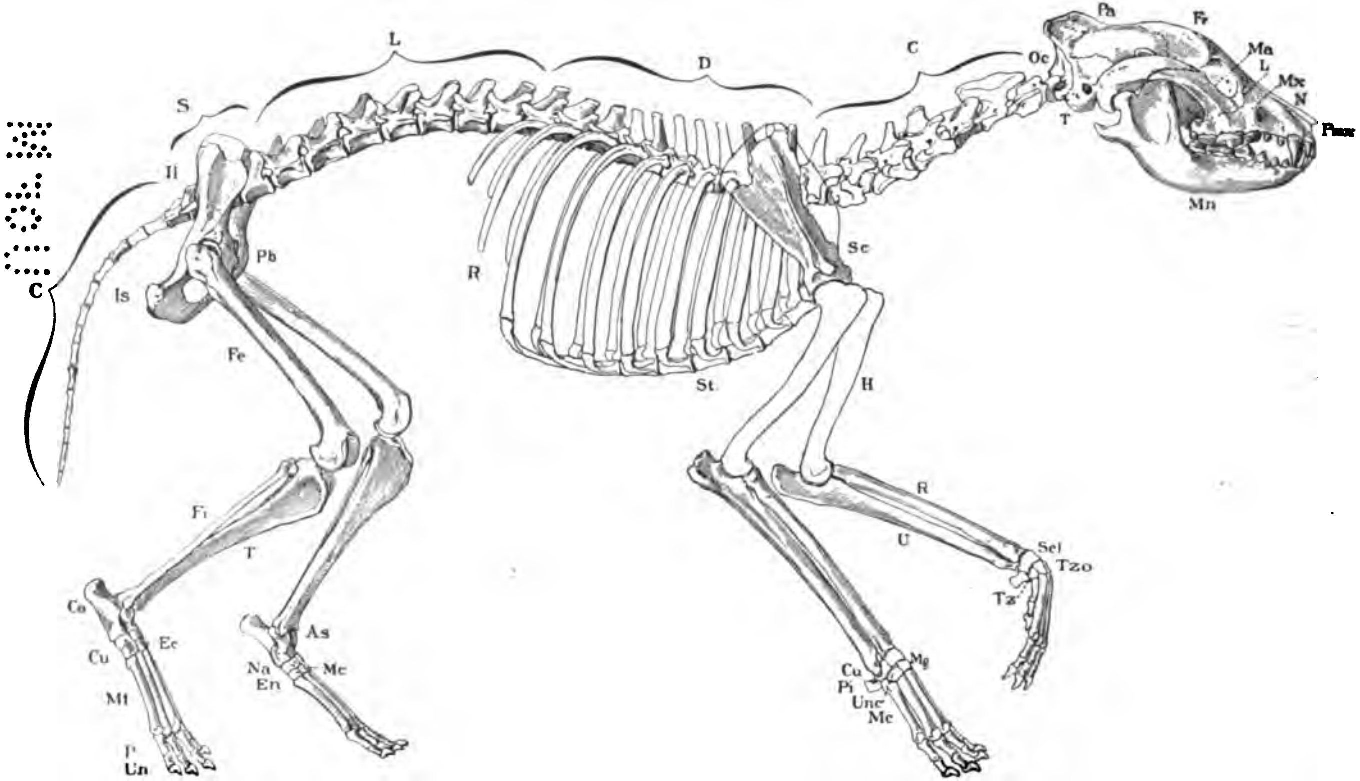
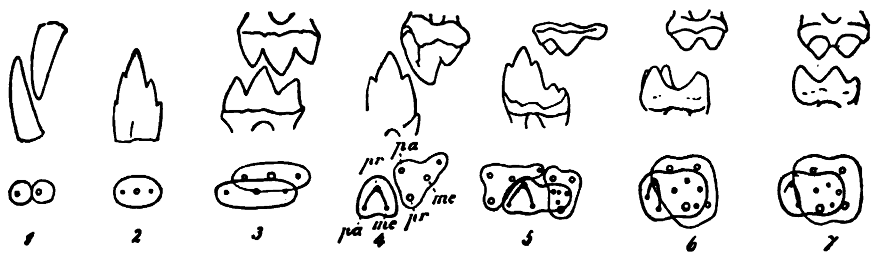


FIG. 37.—*Ælurodon sævus* Leidy; much reduced. Restored from skeleton in collection of E. D. Cope. The unshaded portions supplied. From the Loup Fork (Upper) Neocene of Nebraska.

## Class V.—MAMMALIA.

The primary characters of the Mammalia are seen in their limbs and in their teeth. The general characters of the skeleton may be learned from Fig. 37 (*Ælurodon sævus* Leidy). The mutilate type of limbs is seen in *Cetotherium cephalus* Cope (Fig. 45, facing page 108). The phalanges are connected by integument and form an inflexible paddle, and in the typical forms the elbow is also inflexible. The difference between unguiculate and ungulate phalanges may be seen by comparing Fig. 37 and Fig. 55 (page 119) with Figs. 38 and 39. The compressed curved form of the former, adapted for prehension, is easily distinguished from the flat generally wide type seen in the latter, which is adapted for support. The different carpal and tarsal types of the Ungulata are seen in Figs. 38 and 39. A, is the taxeopodous; B, the proboscidian; C, the amblypodous; and D and E, the diplarthrous, represented by the Perissodactyla (D) and Artiodactyla (E) respectively.

The molar types of dentition in historical and developmental order to the quadritubercular are represented in Fig. 40. Forms up to No. 5, inclusive, predominate in the Unguiculata; and 6 and 7 with their derivatives predominate in the Ungulata. The derivatives of Nos. 6 and 7 are formed by the development of ridges or crests which con-



**FIG, 40.—Diagrams of types of mammalian dentition, from Osborn; *1*, haplodont; *2*, protodont; *3*, triconodont; *4*, tritubercular superior and inferior; *5*, tritubercular superior, tuberculo sectorial lower; *6*, quadritubercular snperior, quinquetuberculur inferior; *7*, quadritubercular, both jaws. *pr*, protocone; *pa*, paracone; *me*, metacone.**

nect the cusps longitudinally or transversely, forming various patterns, two of which are represented in Figs. 59 (page 124) and 63 (page 128). Such types are termed lophodont. Those in which the crests and the grooves between them become respectively elevated and profound are termed ptychodont, Figs. 51 (page 114) and 60 (page 125).

Two subclasses are known to belong to the Mammalia:

| | |
|---|---|
| An interclavicle; a large coracoid articulating with the sternum; | *Prototheria.* |
| No interclavicle; coracoid very small, coössified with scapula; not reaching sternum; | *Eutheria.* |

The Prototheria have one existing order, the Monotremata, and it is supposed, with much probability, that two orders which appear in the Trias and continue until the Eocene, inclusive, belong to it. If this classification is admitted, the Eutheria have their first representatives in the Postcretacic, and their latest are now numerous.

Of the PROTOTHERIA, there are probably three orders of which species are known, but the location of the first two enumerated below is not certain.

| | |
|---|---|
| Incisors reduced; molars with compressed cutting crowns, and undivided roots; | *Protodonta.* |
| Incisors much enlarged; molars with tubercular grinding surfaces, and distinct roots; | *Multituberculata.* |
| No teeth at maturity; | *Monotremata.* |

The families are the following:

*Protodonta;* Dromatheriidæ.

*Multituberculata;* Plagiaulacidæ, Chirogidæ, Polymastodontidæ. *Monotremata;* Ornithorhynchidæ.

The geological range of these orders is shown by the table below:

| | Protodonta | Multituberculata | Monotremata |
|---|---|---|---|
| **Plistocene** . | | | |
| **Neocene** . . | | | |
| **Eocene** . . | | ┃ | |
| **Cretacic** . . | | ┃ | |
| **Jurassic** . . | | ┃ | |
| **Triassic** . . | ┃ | ┃ | |
| **Carbonic** . | | | |
| **Devonic** . . | | | |
| **Siluric** . . | | | |
| **Ordovicic** . | | | |
| **Cambric** . . | | | |
| **Huronic** . | | | |

Species of PROTODONTA have been found thus far only in the Triassic beds of North Carolina. Their molar teeth bear some resemblance to those of some of the corresponding teeth of the Theromorous reptilian genus Dimetrodon. The oldest MULTITUBERCULATA appear in the Trias of South Africa in the Karoo beds, and in the Upper Trias (Keuper) of Würtemburg (Europe). They are more abundant in the Jurassic of England and of the Rocky Mountain region of

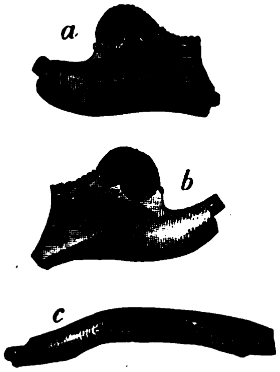


**Fig. 41.**—*Ptilodus mediævus* Cope; mandibular ramus; *a*, *b*, $\frac{1}{1}$; *c*, $\frac{3}{2}$. Original. From Puerco bed of New Mexico.

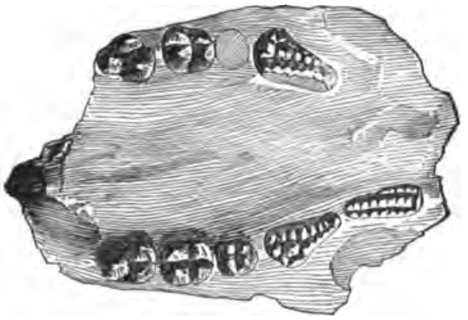


**Fig. 42.**—*Chirox plicatus* Cope; palate and molar teeth, from below, 3-2 natural size. From Puerco bed of New Mexico. Original.

America, and in the later Cretacic of North America and of Patagonia. In the latest Cretacic (Puerco) of New Mexico the largest forms occur, which equal an adult kangaroo (Figs. 41 and 42). The last of them are found in the lowest Eocene in the north of France. Extinct and recent Monotremata are restricted to the Australian realm.

The Eutheria are represented by the following numerous orders:

I. Marsupial pelvic bones (generally); palate perforated; (vagina double; placenta wanting; corpus callosum rudimental; cerebral hemispheres small). (*Didelphia.*)

One deciduous molar tooth shed; the rest permanent; (1) *Marsupialia.*

II. No marsupial bones; palate generally entire; (one vagina; placenta and corpus callosum* well-developed). (*Monodelphia.*)

A. Posterior limbs wanting, or represented by

---

* More recent researches than those of Osborn in 1886, confirm the view of Owen that this element is the hippocampal commissure.—H. F. O.

minute rudiments; anterior limbs oar-like. (*Mutilata.*)

Elbow joint inflexible; carpals discoid, and, with the phalanges, separated by cartilage; lower jaw without ascending ramus; (2) *Cetacea.*

Elbow joint flexible; carpals and phalanges with close articulations; mandible with ascending ramus; (3) *Sirenia.*

AA. Posterior limbs present; ungual phalanges compressed and curved on one or all the feet.* (*Unguiculata.*)

β, Carpal and tarsal bones generally in linear series.

γ, Teeth without enamel; no incisors.

Limbs ambulatory; hemispheres small; (4) *Edentata.*

γγ, Teeth with enamel; incisors present.

No postglenoid process; mandibular condyle not transverse; mastication proal; limbs not volant; hemispheres small; (5) *Glires.*

Anterior limbs volant; hemispheres small; (6) *Chiroptera.*

A postglenoid process; mandibular condyle transverse; mastication orthal; scaphoid and lunar bones not coallesced;† hemispheres small, smooth; (7) *Bunotheria.*

A postglenoid process; limbs not volant, with a scapholunar bone; mastication orthal; hemispheres larger, convoluted; (8) *Carnivora.*

*ββ*, Carpal and tarsal bones alternating; faceted.

Anterior limbs prehensile; mandibular condyle and mastication transverse; (9) *Chalicotheria.*

AAA. Posterior limbs present; ungual phalanges not compressed and hooked.‡ (*Ungulata.*)

*β*, Carpal, and usually tarsal bones in linear series.§

Limbs ambulatory; teeth with enamel; (10) *Taxeopoda.*

*ββ*, Carpal bones alternating externally; tarsals in linear series.

Limbs ambulatory, median digits longest; teeth with enamel; (11) *Toxodontia.*

*βββ*, Tarsal bones alternating; carpals linear or reversed diplarthrous.

Cuboid bone partly supporting navicular, not in contact with astragalus; no canine teeth; (12) *Proboscidea.*

*ββββ*, Both tarsal and carpal series more or less alternating; the distal row inwards.

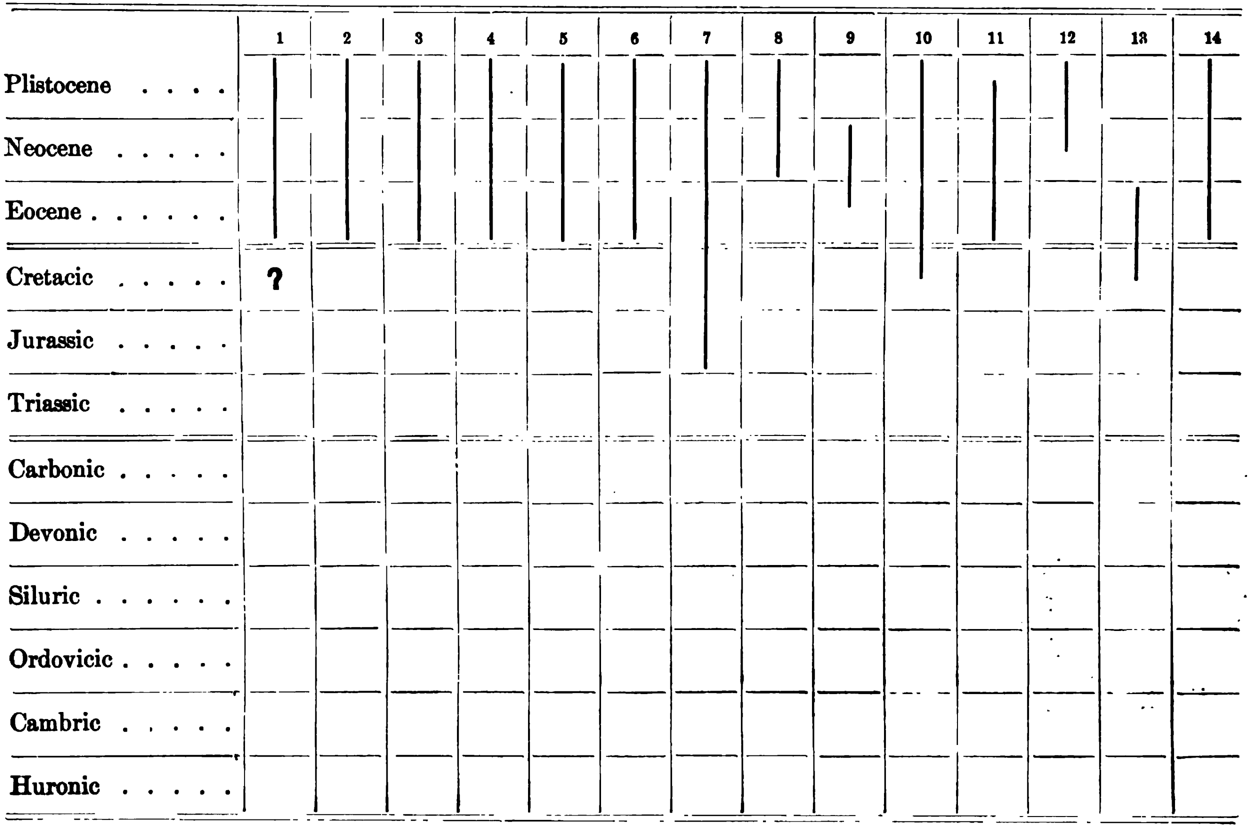
Os magnum not supporting scaphoides; cuboid supporting astragalus; superior molars tritubercular; (13) *Amblypoda.*

Os magnum supporting scaphoides; superior molars quadritubercular; || (14) *Diplarthra.*

The geological range of these orders is as follows:

---

* Except Mesonychidæ, some Glires, and posterior feet of some Edentata.
† Except Talpa and Erinaceus. ‡ Except in the Hapalidæ. § Except in Dendrohyrax.
|| Except Pantolestidæ.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
Plistocene
Neocene
Eocene
Cretacic
Jurassic
Triassic
Carbonic
Devonic
Siluric
Ordovicic
Cambric
Huronic
?

The Marsupialia fall into two suborders, which differ as follows:

| | |
|---|---|
| Incisors $\frac{4 \text{ or } 5}{3 \text{ or } 4}$ | *Polyprotodontia.* |
| Incisors $\frac{1 \text{ to } 3}{1 \text{ to } 3}$ | *Diprotodontia.* |

The Polyprotodontia are carnivorous and insectivorous in their habits, and their present range is Australasia and the two Americas. They are the older of the suborders, being represented in the Eocenes of Europe and North America by species of opossums (Fig. 43). Genera probably allied occur in the Post-cretacic of North America. No large forms are known. The Diprotodontia are now restricted to Australasia, and the extinct forms belong to the Plistocene of the same region. These include some very large kangaroos, with still larger animals of the genera Nototherium and Diprotodon. The *Diprotodon australis* Owen was as large as a rhinoceros, but though allied to the kangaroo, was typical of a different family. The feet were plantigrade, and the fore limbs were larger than the hind limbs.

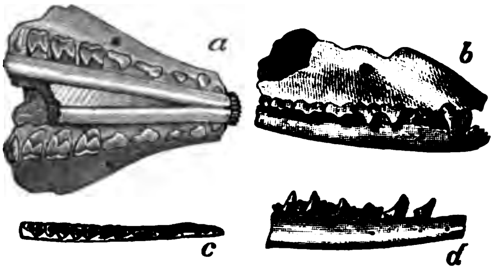


FIG. 43.—*Peratherium fugax* Cope; anterior part of skull. From Lower Neocene (White River bed) of Colorado. X 2. Original.

The CETACEA are represented by three suborders, which differ as follows:

| | |
|---|---|
| External nostrils at middle of muzzle; temporal fossæ elongate, approximated; teeth; | *Archæoceti.* |
| External nostrils at base of muzzle; temporal fossæ short, lateral; teeth; | *Odontoceti.* |

External nostrils at base of muzzle; temporal fossæ short, lateral; no teeth, but transverse horny laminæ on the upper jaw; *Mysticeti.*

FIG. 44.—*Zeuglodon cetoides* Owen; skull, much reduced. From Eocene of Alabama. From Gaudry.

The Archæoceti are few in number, and are chiefly represented by the gigantic Zeuglodon (Fig. 44.) They are not known before or after the Eocene system, nor out of the geographical area of the Northern Hemisphere. The Odontoceti first appear in the older Neocene, and the oldest family, the Squalodontidæ, have the posterior teeth two-rooted, as in the Zeuglodons. The other families with one-rooted teeth were contemporary with them, and are represented in the present seas by numerous types, as the dolphins, sperm whales, etc. The Mysticeti, or whalebone whales, appear in the Lower Neocene, and are still abundant. They include the largest vertebrates. (Fig. 45.)

The Odontoceti and Mysticeti are probably independent descendents of the Archæoceti. The former retain their dental and rib characters, but the nasal bones are more abbreviated than in the Mysticeti. In certain Mysticeti of the Neocene the frontals as well as the nasals are somewhat elongate, and some (*e. g.*, Cephalotropis) have temporal ridges.

SIRENIA first appear in a very generalized family in the Eocene beds of some West Indian Islands. In the Neocene of Europe and North America forms approaching more nearly to the existing types are not rare, especially in the south of Europe. At present, species exist on the shores of the continents in the warmer latitudes. (Fig. 46.)

The succession of types in this order is measured by the modifications in the dentition. In the Eocene Prorastomidæ we have a nearly normal dentition with distinct canines. In the succeeding forms canines are wanting and the incisors are either enlarged or disappear. Thus, in the Neocene Halitheriidæ we have nearly normal molar dentition, with incisors reduced in number and functioning as digging tusks. The existing dugongs continue the enlarged incisors, but the molars are reduced in number, and have become simple prisms. The also existing Manatees have lost the incisors, retaining normal molars which have abnormally increased in number. In the lately extinct Rhytinidæ all dentition has disappeared.

The EDENTATA have been generally restricted to the Southern Hemisphere, although during the Neocene they ranged as far north as the Ægean Sea in Europe, and to latitude 46° in North America during the Plistocene. They first appear in the Eocene of Patagonia, and were extremely common in the Neocene throughout tropical America, where they are still abundantly represented. A few species still remain in the Ethiopean and Paleotropical geographical realms. The Megatheriidæ of the South American Neocene were of large and gigantic size, the largest species pertaining to the genus Megatherium, which ranged in North America to South Carolina. The Glyptodontidæ were covered with an immovable carapace consisting of bony tesseræ, somewhat like that of armadillos. They varied in size from that of a sheep to that of a rhinoceros. Species were abundant in the Neocene of South America, when they also ranged north to Texas, Florida, and Kansas. The most ancient (Eocene) Edentata display traces of enamel on the teeth.

The Glires are found in the strata of all regions, but in reduced numbers in the Eocene in all countries except temperate South America, where they were abundant at that age. There are four suborders, which differ as follows:

I. Fibula not articulating with calcaneum; ankle and elbow not tongued and grooved; one pair of incisors in upper jaw.

| | |
|---|---|
| Incisive alveolus not passing into centre of ramus of lower jaw; fibula distinct; | *Hystricomorpha.* |
| Incisive alveolus penetrating ramus; fibula distinct; | *Sciuromorpha.* |
| Incisive alveolus penetrating ramus; fibula coössified with tibia; | *Myomorpha.* |

II. Fibula articulating with calcaneum; ankle and elbow tongued and grooved; two incisors in upper jaw.

| | |
|---|---|
| Inferior incisor penetrating ramus; fibula and tibia coössified; | *Lagomorpha.* |

The Hystricomorpha (porcupines, cavies, etc.) are abundant in the Eocene of South America, and are present in the Upper Eocene of France. They are more abundant in the Neocene of South America and France, and are present in the Upper Neocene of North America. At present they are cosmopolitans, excepting Australia, but they chiefly abound in South America. (Fig. 47.) The

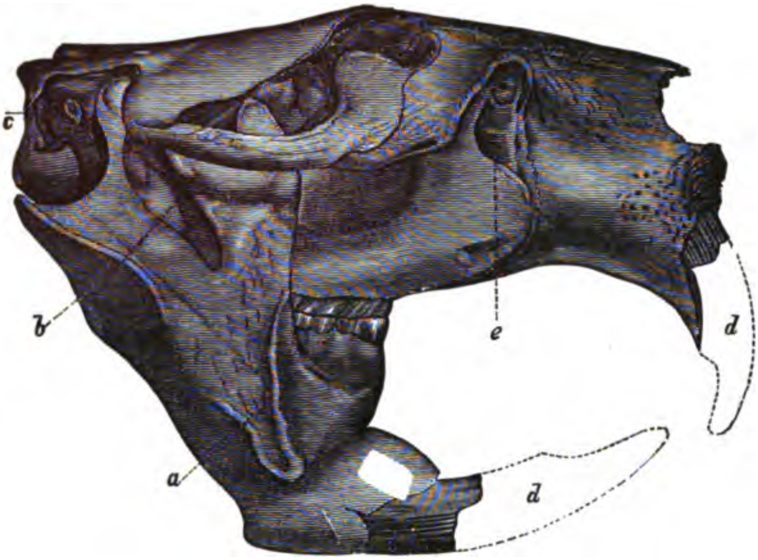


FIG. 47.—*Castoroides ohioensis* Foster; skull, much reduced. From Plistocene of Ohio. From Hall and Wyman.

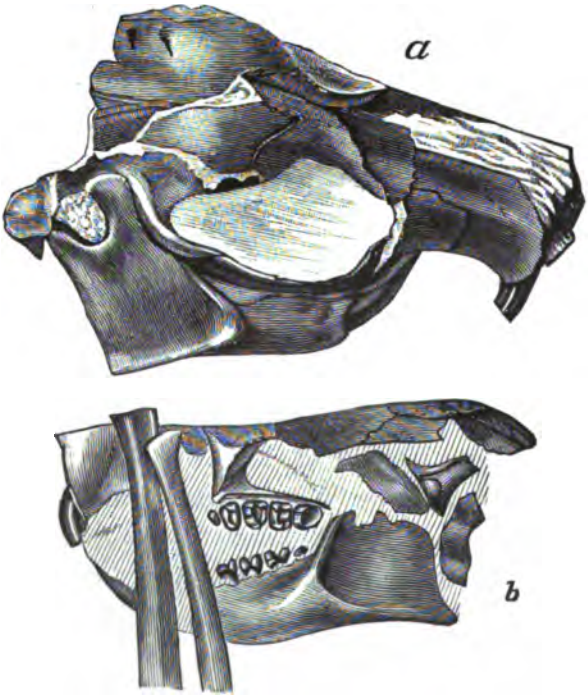


FIG. 48.—*Plesiarctomys delicatissimus* Leidy; Skull. From Eocene of Wyoming. Original.

Sciuromorpha only occur fossil in the Northern Hemisphere, and are the principal Glires of the Eocene. From that period they became more abundant in both North America and Europe, reaching their highest expression in the beaver, and spread into South America. (Figs. 48–49.)

The Myomorpha (mice, rats, etc.) have a few supposed representatives in the Eocene of Patagonia, but only certainly begin in the Neocene in the Northern Hemisphere. The dormice are peculiar to European beds, and the pocket-gophers to North America. They cover the earth, including a few forms in Australia, at the present period. (Fig. 50.)

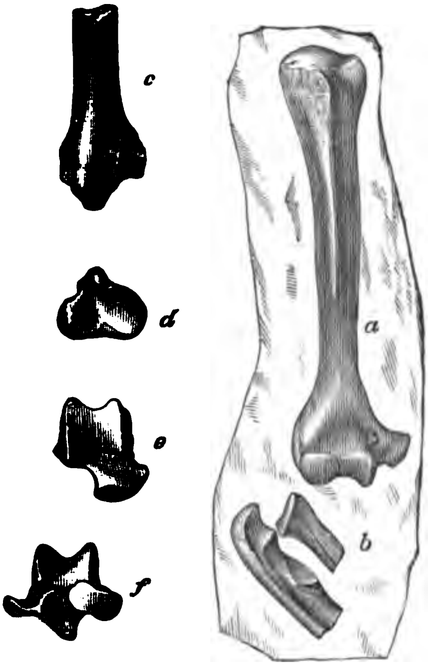


**FIG. 49.—*Plesiarctomys delicatissimus* Leidy; *a*, humerus; *b*, proximal ends of ulna and radius; *c*, *d*, tibia, distal end; *e*, *f*, astragalus; all natural size. From Eocene of Wyoming.**

The Lagomorpha (rabbits) appear first in the lowest Neocene of North America (White River), and continue to the present day. They appear in Europe at about the same time, but not in South America until the Plistocene. (Fig. 51.)

The CHIROPTERA (bats) includes two primary divisions at the present time, the insectivorous (Animalivora) and the frugivorous (Frugivora), which differ as follows:

Crowns of molar teeth Vs; those of opposite jaws interlocking in mastication; *Animalivora.*

Crowns of teeth obtuse, not interlocking in mastication; *Frugivora.*

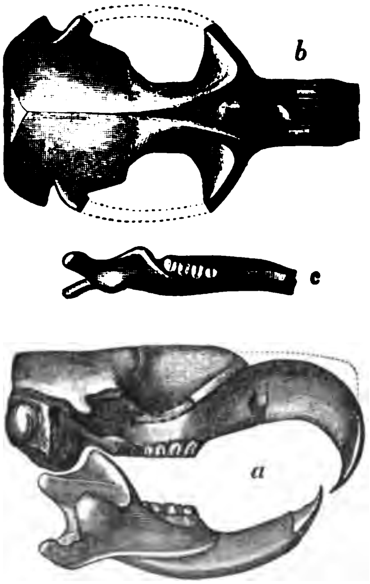


FIG. 50.—***Entoptychus crassiramis*** **Cope; a pocket-gopher from the Middle Neocene of Oregon, natural size. Original. *c*, lower jaw from above.**

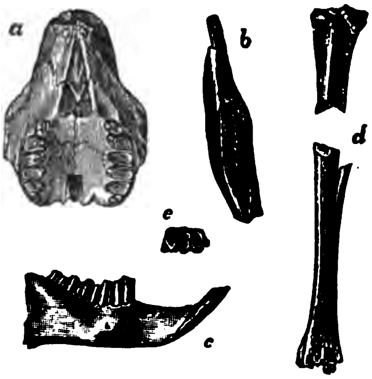


FIG. 51.—***Palæolagus haydenii*** **Leidy; a rabbit from the lower Neocene of Colorado. Original; natural size; *a*, anterior half of skull, from below; *b*, *c*, lower jaw; *d*, tibia and fibula, from front; *e*, tibia and fibula, from below.**

Animalivora appear in typical forms in the Lower Eocene (Wasatch) in North America, and the Upper Eocene (phosphorites) in France.

The Frugivora (flying foxes) present a degenerate dentition; they are not known in the fossil state.

The BUNOTHERIA present four suborders, which are characterized as follows:

Molars 8 or more; incisors several, with closed roots; *Pantotheria.*

Molars 7 or less; incisors with closed roots, not enlarged; fibula distinct; otic bulla developed; *Creodonta.*

| | |
|---|---|
| Molars 7 or less; canine generally small, incisors generally enlarged; fibula generally united with tibia; | *Insectivora.* |
| Molars 7 or less; incisors few, growing continually from open roots; | *Tillodonta.* |
| Incisors much enlarged, growing from persistent pulps, the superior with enamel in anterior and posterior bands, and hence truncate; | * *Taeniodonta.* |

The Pantotheria are the most ancient of the Eutherian Mammalia, appearing rather abundantly in the Jurassic of Europe and North America. They are all of small size. The Creodonta represent the Carnivora in the Postcretacic and Eocene systems. They have (except in one family) more than one sectorial molar, and these are true molars, and not premolars. They have (except in one family) strong canines. They range in size from that of an opossum (Stypolophus sp.) to that of a grizzly bear (Hemipsalodon sp.). They are found in the horizons mentioned in North America, Europe, and South America. A few species (Hyænodon, etc.) remain over in the Lower Neocene (White River). (Fig. 52.)

Undoubted Insectivora appear in the Upper Eocene of France, but supposed members of the suborder occur in the Lower Eocene of the same. In America none are certainly known prior to the Lower Neocene (White River). They are rare in all formations in America, but they are abundant in the Middle Neocene of Europe, and in later beds, where forms of moles, shrews, and hedgehogs are abundant. The enlargement of the incisors seen in the Insectivora reaches its extreme in the Tillodonta, where they grow from persistent pulps, as in the Glires. These animals first appear in the Postcretacic of North America, and are not

---

*Tertiary vertebrata, 1883, p. 186. This order is equal to the Calamodonta of Cope and the Ganodonta of Wortman.—Ed.

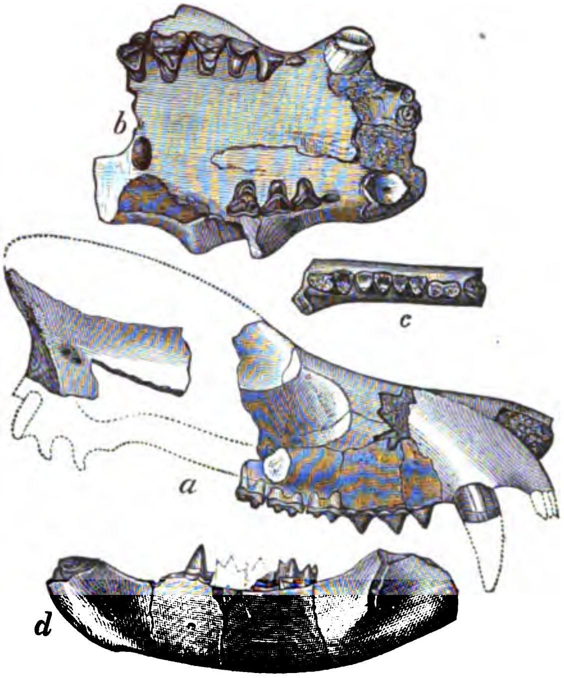


FIG. 52.—*Deltatherium fundaminis* Cope; portions of skull, two-thirds natural size. From Puerco beds of New Mexico. *a*, skull profile; *b*, from below: *c*, fragment of lower jaw, from above; *d*, do., from outer side.

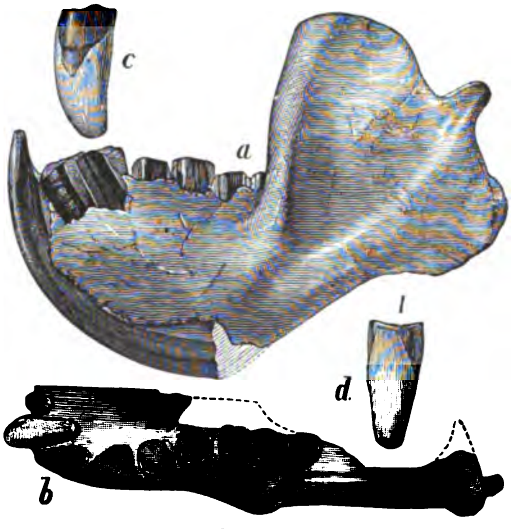


FIG. 53.—*Calamodon simplex* Cope; lower jaw, one-third natural size. From Wasatch Eocene of Wyoming. *b*, from above; *c d*, an isolated molar.

uncommon in the Eocene of America, with one form in the Eocene of Switzerland. Later than that age they are unknown. (Fig. 53). The Creodonta are probably the ancestors of the Carnivora and Insectivora, and the Tillodonta of the Glires. The Pantotheria are ancestors of the Creodonta. The time relations of the Bunotherian orders are expressed in the following table:

| | Pantotheria | Creodonta | Insectivora | Tillodonta |
|---|---|---|---|---|
| Plistocene . . . | | | ┃ | |
| Neocene . . . | | ┃ | ┃ | |
| Eocene . . . . | | ┃ | | ┃ |
| Cretacic . . . . | ? | ? | | ┃ |
| Jurassic . . . . | ┃ | | | |
| Triassic . . . . | | | | |
| Carbonic . . . . | | | | |
| Devonic . . . . | | | | |
| Siluric . . . . . | | | | |
| Ordovicic . . . | | | | |
| Cambric . . . . | | | | |
| Huronic . . . . | | | | |

True Carnivora are definitely known from the beginning of the Neocene, and it is probable that they already existed in the Upper Eocene in Europe. There are two suborders, which differ as follows:

Digits distinct; posterior limbs free; *Fissipedia.*

Digits united into paddles by integument; hind limbs partly enclosed in general integument; *Pinnipedia.*

The Fissipedia have their closest connection with the Creodonta, where the latter exhibit exceptionally a dentition like the dogs, in the family Miacidæ. From the dogs development has pursued two principal lines. The one has tended to an omnivorous diet, and has terminated in the bears. The other has tended to an exclusively carnivorous diet, and has ended in the cats, which display the characters of the order in the greatest perfection. True bears appear in the Plistocene, and cats (Fig. 54) and hyænas in the Upper Miocene, in the Northern Hemisphere. In the Southern Hemisphere cats do not appear until the Plistocene (Fig. 55), and hyænas do not occur in the Western

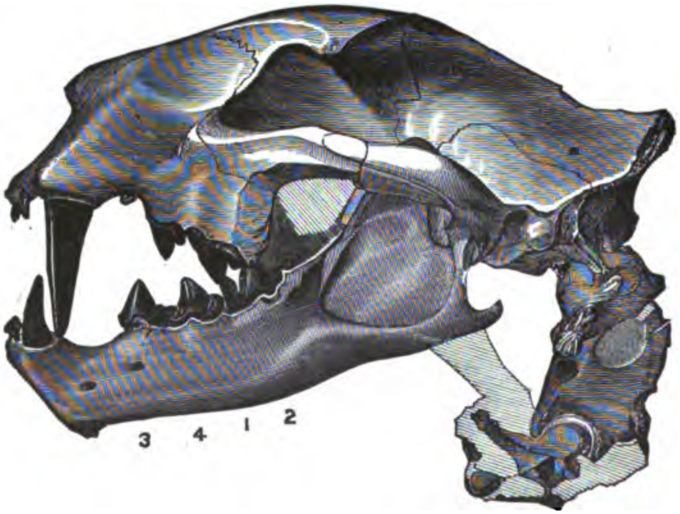


**Fig. 54.**—*Nimravus gomphodus* **Cope, two-fifths natural size; left side of skull. From Miocene of Oregon. 3-4, premolars; 1-2, true molars.**

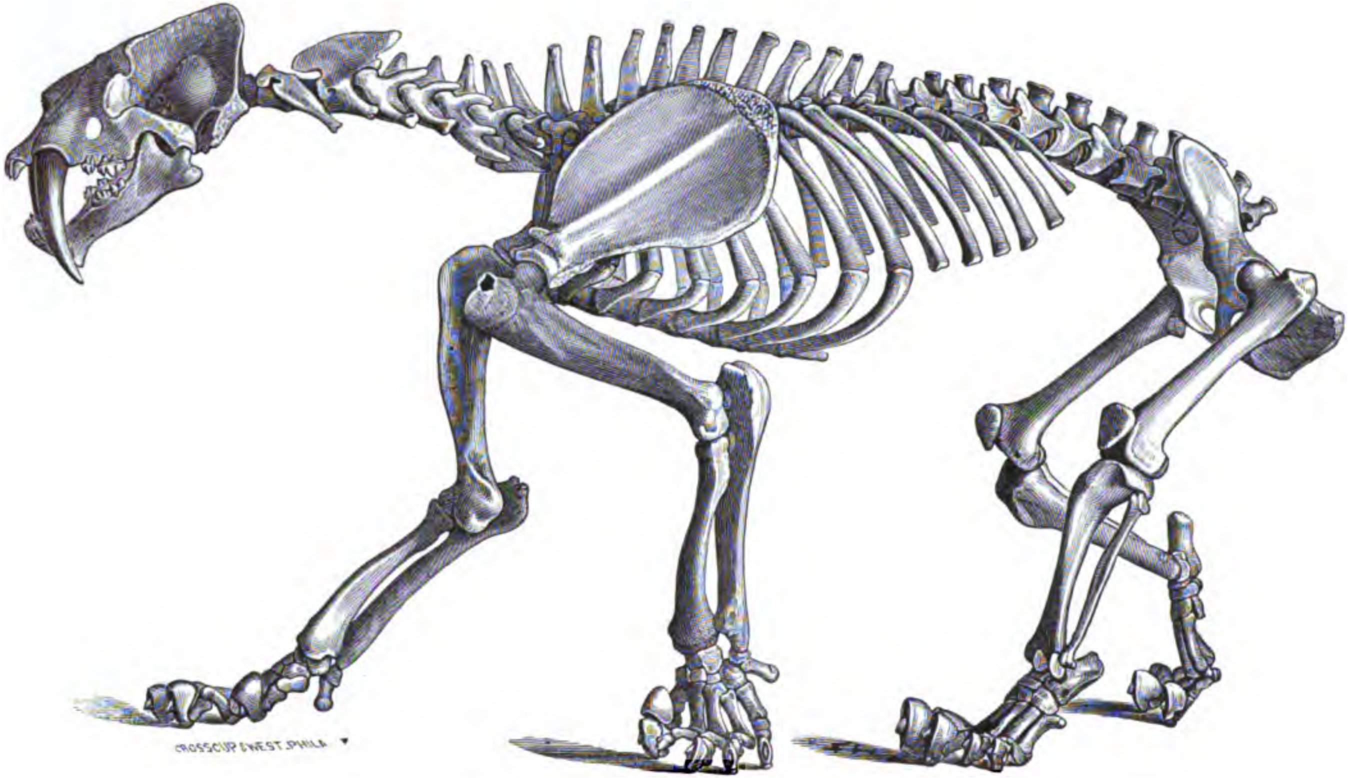


FIG. 55.—*Smilodon neogæus* Lund. From the Pampean formation of Buenos Ayres. After Burmeister.

Hemisphere. Dogs are very abundant throughout the Neocene, except in the southern continents, where they do not appear till the Plistocene (Fig. 37).

The Pinnipedia appear later in geologic time than the Fissipedia, no forms being known of an age prior to the Middle Neocene. The earliest forms are of two types related to the true (earless) seals and walruses respectively. Of the primitive affinities of the Pinnipedia nothing is known, but they are suspected to have had connection with the Creodonta.

The CHALICOTHERIA is a group which includes but few species, which have been found in India, Europe, and North America. They possibly appear in Europe in the Upper Eocene, and occur in the successive stages of the Neocene, beyond which they did not continue. Their characters are very peculiar, including long fore legs and short hind ones, with claws and digits like sloths, but dentition like perissodactyle ungulates. The largest species equaled a grizzly bear.

The order TAXEOPODA includes the following suborders:

I. ? No clavicle.

| | |
|---|---|
| Astragalus not interlocked laterally with the tibia; fibula not articulating with calcaneum; head of astragalus rounded; canines; no anapophyses; | *Condylarthra.* |
| Astragalus not interlocked with tibia; fibula articulating with calcaneum; astragalus head flat; canines; | *Litopterna.* |
| Astragalus interlocking at side with tibia; fibula not articulating with calcaneum; head of astragalus flat; no canines; | *Hyracoidea.* |

II. Clavicles present.

LEVYTYPE CO. PHILA

FIG. 56.—*Phenacodus primævus* Cope, one-seventh natural size. From Wasatch Eocene.

Incisors growing from persistent pulps; anapophyses; *Daubentonioidea.*[*]
Incisors with closed roots; anapophyses; *Quadrumana.*
Incisors with closed roots; no anapophyses; *Anthropomorpha.*

The Condylarthra are characteristic of the Postcretacic in North America, and the Lower Eocene of both continents. They have not yet been detected in the Southern Hemisphere. Their characters connect inseparably the Ungulata and Unguiculata divisions, since the carpus and tarsus are like those of the latter, while the ungues are hoofs or semihoofs. The molars are tritubercular, quadritubercular or lophodont. The best known genus is Phenacodus (Fig. 56), which is the synthetic type of all ungulates. In the known Condylarthra there are five digits on all the feet.

The Litopterna are only known, so far, from the Cenozoic of South America, ranging throughout the entire series. The teeth present the variations seen in the Perissodactyla, some being bunodont and some lophodont, but the bunodont forms are tritubercular, like the lowest Condylarthra. This group displays a remarkable reduction in the digits as in the Perissodactyla, passing to three and one digit, as in the horse line.

The Hyracoidea are only known in the recent state in Africa and Western Asia. Their molar dentition is lophodont, while the incisors approximate somewhat the rodent pattern. In like manner Daubentonioidea are only known as recent in Madagascar. They are allied to the lemurs.

Quadrumana appear in the Lower Eocene in North America and Europe as lemurs (Fig. 57). True monkeys do not appear until the Middle Neocene in the Old World, while they are absent from North America, and occur in the Plistocene of South America. The Anthropomorpha (Fig. 58) appear first in the Middle Neocene of France and

---

[*] The horny coverings of the terminal phalanges of all but the first digit in the only known genus, are claw-like.

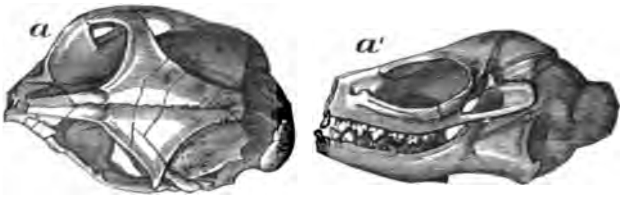
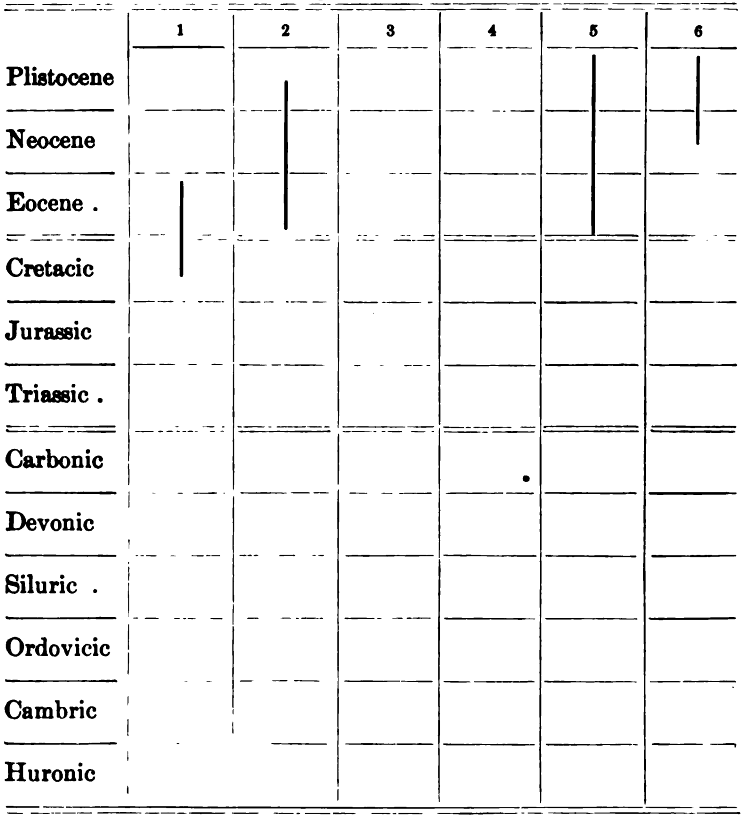


FIG. 57.—*Necrolemur antiquus* Filh; a lemur from the Upper Eocene of France, natural size. From Filhol.

the Upper Neocene of India, but man does not appear until the Plistocene in both America and Europe. The exact stage of the Plistocene at which man's remains have been found is not clearly ascertained, but he was contemporary with various extinct species and genera of Mammalia in both Europe and North and South America. The time history of the Taxeopoda may be expressed as follows:



The TOXODONTIA are confined to the South and Central American continents. They appear first in the Eocene of Patagonia and continue through the Plistocene system. These later representatives of the genus Toxodon reached the size of the largest species of rhinoceros. The teeth are lophodont, and early began to be prismatic, and to grow from persistent pulps. This condition appeared first in the incisors, some of which resemble somewhat those of rodents, and later in the molars. There are two suborders of Toxodontia which differ as follows :

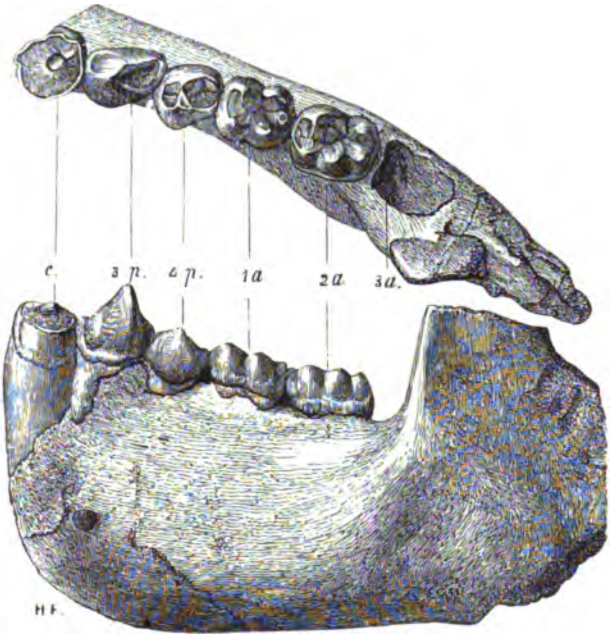


**FIG. 58.—*Dryopithecus fontani* Lart.; anthropoid ape from Middle Neocene of France; ramus of lower jaw, natural size. From Gaudry.**

| | |
|---|---|
| Femur with third trochanter ; a clavicle ; | *Typotheria.* |
| Femur without third trochanter ; no clavicle ; | *Barytheria.* |

The known species of Typotheria have five anterior, and four or five posterior digits, and they are of medium and small size. The known Barytheria have three digits on each foot, and the later forms reached large proportions, with heavy body and short legs.

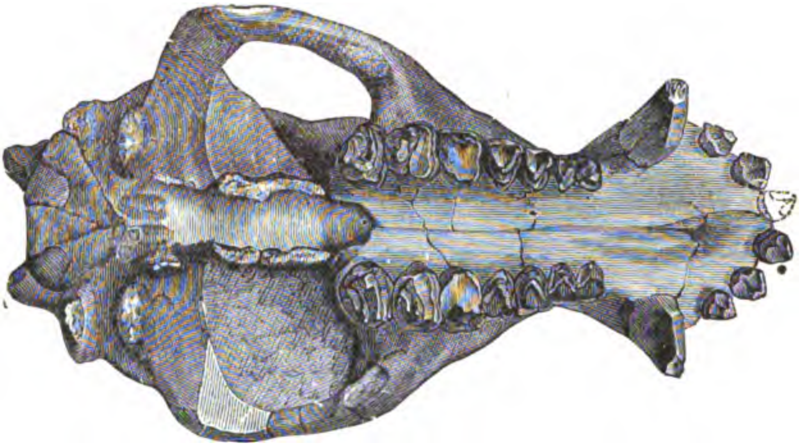


FIG. 59.—*Coryphodon elephantopus* Cope; skull; from below, 2-9 natural size. Original. From the Wasatch Eocene of New Mexico.

The AMBLYPODA are, restricted to the Northern Hemisphere, and to the Postcretacic and Eocene systems, where their remains abound both in Europe and North America. They are the only order of Ungulata with superior molars constructed on a tritubercular basis, and the inferior molars on the tuberculo-sectorial pattern. The earlier forms from the Puerco are the smallest; those of the Lower Eocene (Suessonian, Wasatch) are next in size (Fig. 59); while those of the Middle Eocene (Bridger), which have been found in North America only, are often of gigantic size (Dinocerata) (Fig. 60), and have the cranium adorned with horny processes.

There are three well-marked suborders of this order, with the following characters:

| | |
|---|---|
| Astragalus with a head; femur with third trochanter; superior incisors present; | *Taligrada.* |
| Astragalus without head; a third trochanter and superior incisors; | *Pantodonta.* |

Astragalus without head ; no third trochanter
nor superior incisors ; *Dinocerata*.

The Taligrada are confined to the Postcretacic epoch; the Pantodonda to the Lower, and the Dinocerata to the Upper Eocene.

The order Proboscidia is unknown prior to Middle Neocene time in the northern part of the Eastern and Western Hemispheres, and late Neocene or Plistocene time in South America. In other parts of the Southern Hemisphere they are unknown, although one of the two living species (*Elephas africanus*) is restricted to Africa (Fig. 60). The earliest forms of Proboscidia are Dinotheria and Mastodons (Fig 61), which reached huge dimensions. Elephants appear in late Neocene times in India, and spread in later epchs over North America and Europe. In America their remains are not known from south of the valley of Mexico. The hairy mammoth (*Elephas primigenus* Blum.) was a contemporary of prehistoric man in the Old World, and probably in the New.

FIG. 60 —*Elephas indicus* L; superior molar tooth, reduced. From Tomes, after Owen.

The Diplarthra include the most specialized types of Mammalia as regards the structure of the skeleton, dentition, and digestive system, but they are inferior to the anthropomorphous suborder of the Taxeopoda in the structure of the brain.

There are two suborders, as follows :

Feet with the third digit of predominating

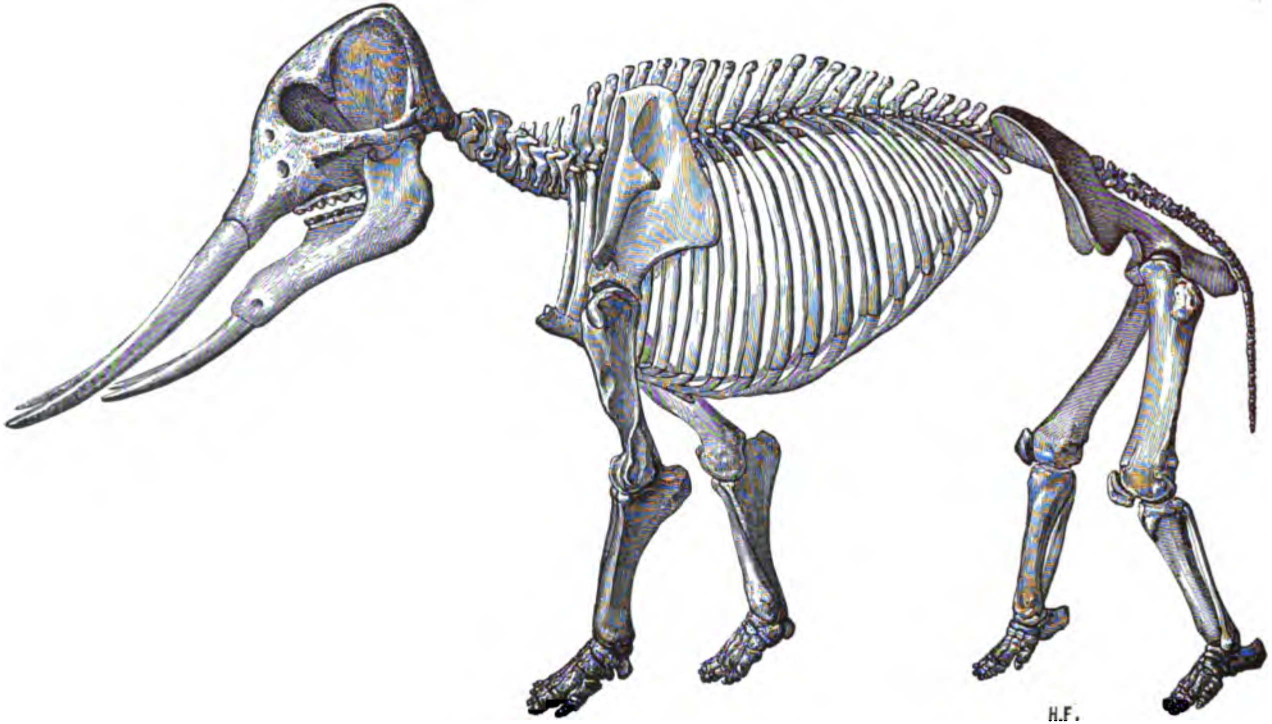


FIG. 61.—*Tetrabelodon augustidens* Cuv. From Gaudry, From the Upper Neocene of France. Specimen in Museum, Paris.

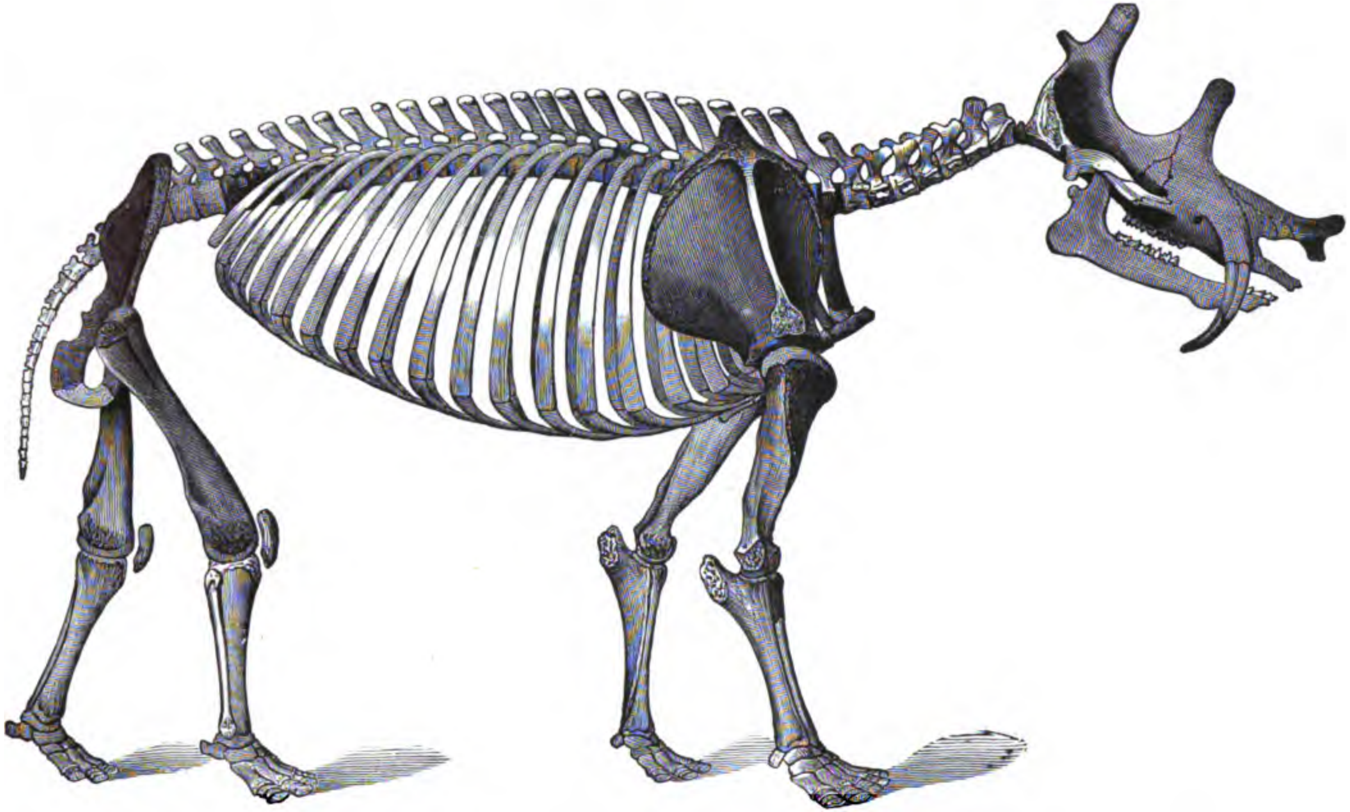


FIG. 62.—*Loxolophodon cornutus* Cope; skeleton, restored, 1-20 natural size. Original. From the Bridger Eocene of Wyoming.

dimensions; distal end of astragalus not forming a ginglymus; *Perissodactyla.*

Feet with the digits 3 and 4 predominating and subequal; astragalus with a distal ginglymus; *Artiodactyla.*

The Perissodactyla exhibit various series of forms in which the toes diminish in number, from four in front and

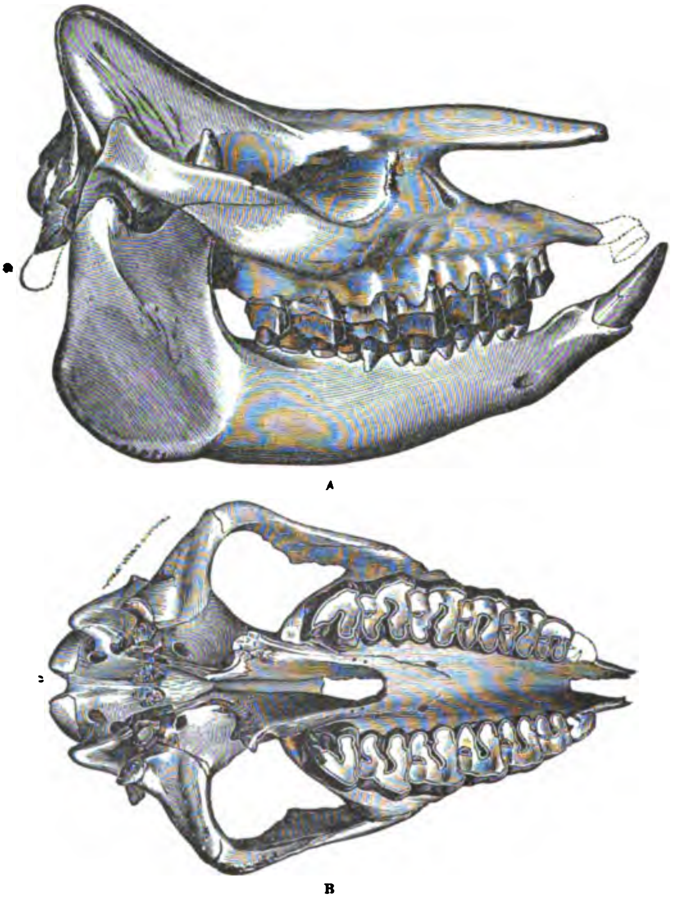


Fig. 63.—*Aphelops megalodus* Cope, one-sixth natural size; *B*, inferior view of cranium, Original. Hornless rhinoceros from the Loup Fork Neocene, Colorado.

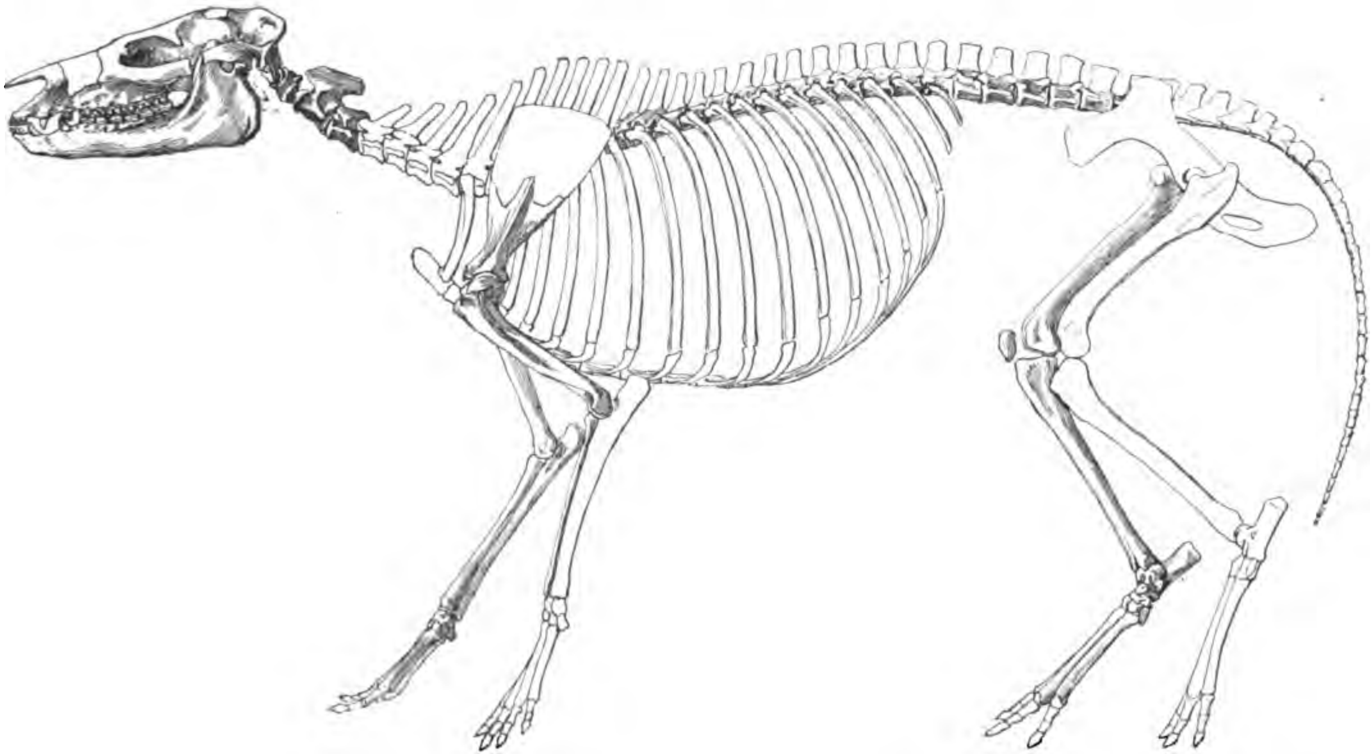
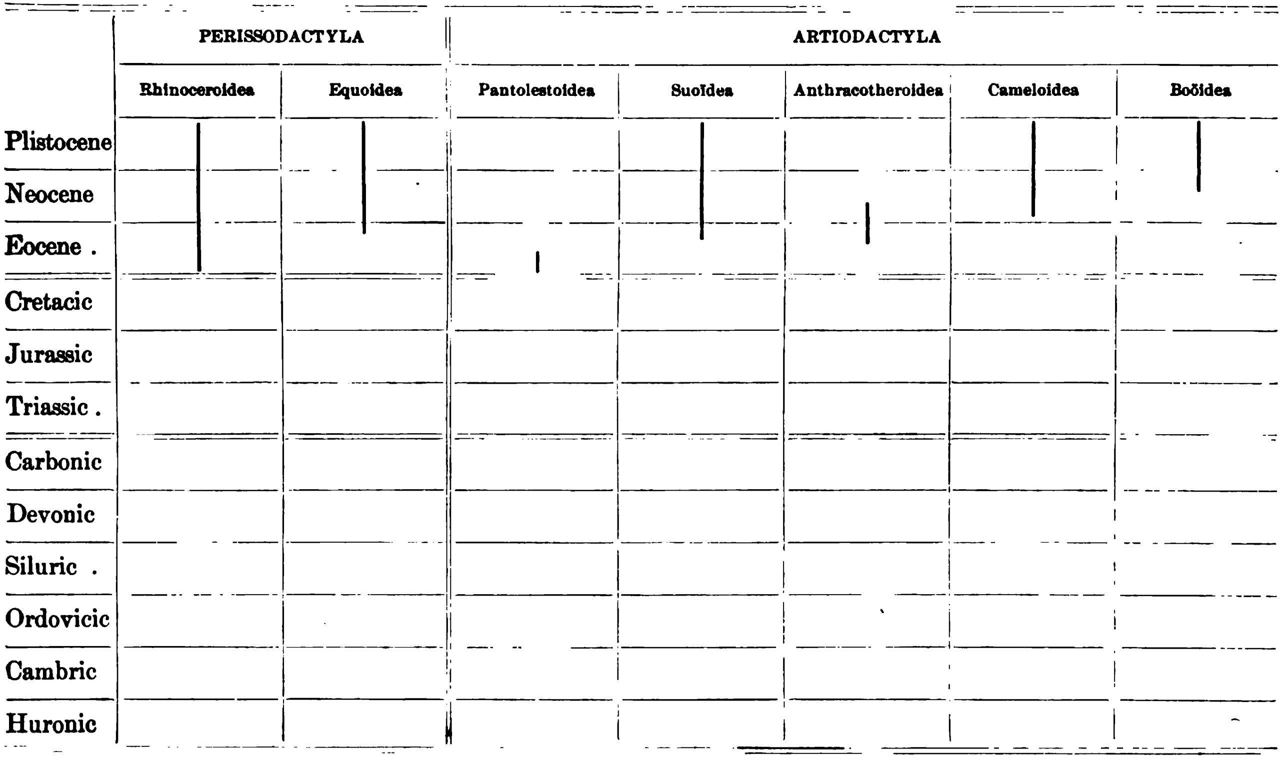


FIG. 64.—*Hyracotherium venticolum* Cope; skeleton restored, one-third natural size. From the Wasatch beds of Wyoming, N. A. Original, except ribs, which are after Osborn. Unshaded portions not preserved in specimen, which is in collection E. D. Cope.

three behind, to one on all the feet (the horse). They may be considered under two heads with respect to the structure of their superior molars, viz.: first those in which the external wall of the crown does not form two Vs (Rhinocerotoidea), and those in which such Vs are present, with the angles directed inwards (Equoidea). Each series includes several families, mostly extinct; in the former the rhinoceros (Fig. 63) and tapir, and in the latter the horse, are still living. The earliest forms belong to the former division, and some of them (Hyracotherium, Fig. 64) have the superior molars almost quadritubercular. They appear first in the lowest Eocene. Three-toed horses first appear in the Lower Neocene, and one-toed horses in the Upper Neocene.

The Artiodactyla are represented by a great variety of forms, which differ primarily in their dental characters. Thus the oldest type (Trigonolestoidea) has tritubercular superior molars. Of the remainder, one series (Suöidea) have the molars quadritubercular, or more highly tubercular. The remaining types have the tubercles of the molars more or less flattened on one side, so as to give crescentic figures on section (Fig. 65), and are hence called selenodont. In some of these there are five crescents (Anthracotheroidea); in the other there are only four. The latter may have most of the premolars simple (Cameloidea, Fig. 65) or complex (Boöidea). Some types of the former and all of the latter lack superior incisor teeth, and have the cuboid and navicular bones coössified. The Boöidea culminate in forms with horns or bony processes of the skull, which may be permanent (Bovidæ, or annually shed (Cervidæ). These divisions appear in geological time in the order of structural modification as here mentioned. This appearance is represented, together with the divisions of the Perissodactyla, in the following table:


PERISSODACTYLA
ARTIODACTYLA
Rhinoceroidea
Equoidea
Pantolestoidea
Suoidea
Anthracotheroidea
Cameloidea
Boöidea
Plistocene
Neocene
Eocene .
Cretacic
Jurassic
Triassic .
Carbonic
Devonic
Siluric .
Ordovicic
Cambric
Huronic

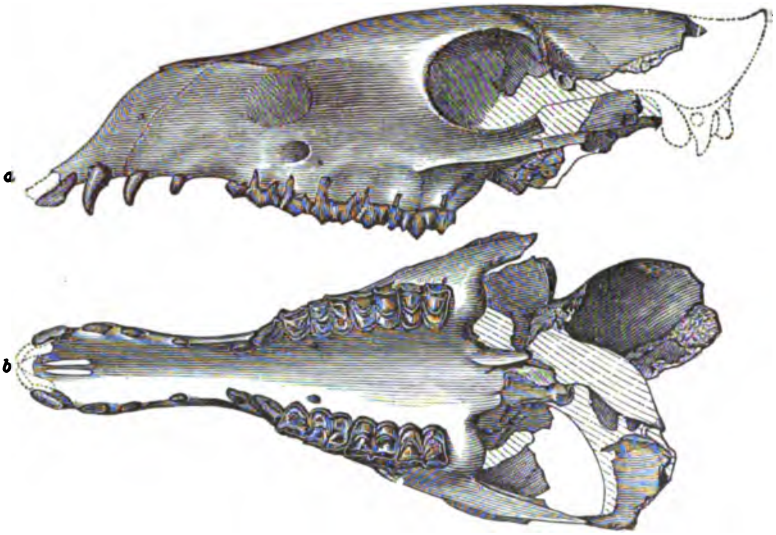


FIG. 65.—*Protolabis transmontanus* Cope; skull, one-third natural size. A Cameloid from the Ticholeptus bed of Oregon. *a*, from left side; *b*, from below. Original.

Of the superfamilies which continue to the present day the existing species are few in number, with the exception of the Boöidea. All except the Boöidea are now restricted to tropical and subtropical regions, and while the majority of Boöidea have the same distribution, there are many species in temperate regions, and a few dwell within the Arctic Circle.

The above table includes only the most important of the superfamilies of the Diplarthra. Those of the Perissodactyla are equally distributed on both sides of the Northern Hemisphere, but only modern forms of the Equoidea appear in South America and in late Neocene time. Pantolestoidea have been so far found in North America only, and the other superfamilies are relatively rare in that continent, except the Cameloidea, which are more abundant than in the Old World. This and the Boöidea only appear in South America in the late Neocene.

As in the Perissodactyla there is a reduction of the digits in most of the lines of the Artiodactyla, which reaches its extreme in the Cameloidea, and in the Boöidea. In the most specialized types of these superfamilies but two digits remain, and the metacarpals of these are fused into a single bone, the "cannon bone." This structure first appears in time in the latest Neocene. (Fig. 66.)

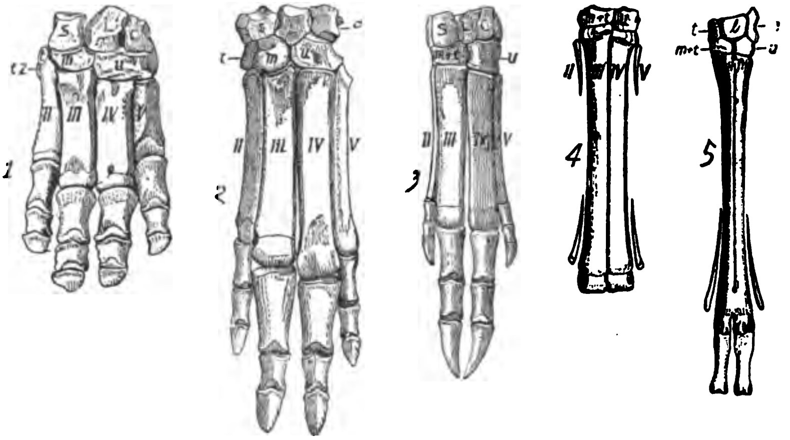


FIG. 66.—Anterior feet of Artiodactyla, with both series of carpals, except in No. 4. From Kowalevsky. No. 1, Hippopotamus; 2, Hyopotamus; 3, Dorcatherium; 4, Gelocus; 5, Cervus.

The families embraced in the orders of Eutherian Mammalia are the following:

MARSUPIALIA; (*Polyprotodontia*); Triconodontidæ, Amphitheriidæ, Myrmecobiidæ, Dasyuridæ, Didelphidæ, Peramelidæ; (*Diprotodontia*); Phascolomyidæ, Phalangistidæ, Tarsipedidæ, Diprotodontidæ, Macropidæ, Thylacoleonidæ.

CETACEA; (*Archæoceti*); Zeuglodontidæ; (*Odontoceti*); Squalodontidæ, Platanistidæ, Physeteridæ, Delphinidæ, (*Mystacoceti*); Balænidæ.

SIRENIA; Prorastomidæ, Halitheriidæ, Manatidæ, Halicoridæ, Rhytinidæ.

EDENTATA ; Orycteropodidæ, Manidæ, Bradypodidæ, Megatheriidæ, Myrmecophagidæ, Dasypodidæ, Glyptodontidæ.

GLIRES ; (*Hystricomorphæ*) ; Paradoxomyidæ, Hystricidæ, Echinomyidæ, Octodontidæ, Capromyidæ, Caviidæ, Chinchillidæ ; (*Sciuromorpha*) ; Sciuridæ ; (*Myomorpha*) ; Dipodidæ, Muridæ, Myoxidæ, Saccomyidæ, Microtidæ, Lophiomyidæ, Bathyergidæ ; (*Lagomorpha*) ; Leporidæ.

CHIROPTERA ; (*Animalivora*) ; Phyllostomidæ, Desmodontidæ, Rhinolophidæ, Noctilionidæ, Vespertilionidæ, Emballonuridæ ; (*Frugivora*) ; Pteropidæ.

BUNOTHERIA ; (*Pantotheria*) ; Amblytheriidæ ; (*Creodonta*) ; Mesonychidæ, Esthonychidæ, Arctocyonidæ, Miacidæ, Hyænodontidæ ; (*Insectivora*) ; Leptictidæ, Centetidæ ; Galeopithecidæ, Tupæidæ, Solenodontidæ, Macroscelididæ, Talpidæ, Adapisoricidæ, Mythomyidæ, Scalopidæ, Chrysochloridæ, Erinaceidæ, Myogalidæ, Soricidæ ; (*Tillodonta*) ; Tillotheriidæ ; (*Tæniodonta*) ; Ectoganidæ, Stylodontidæ.

CARNIVORA ; (*Fissipedia*) ; Cercoleptidæ, Procyonidæ, Æluridæ, Canidæ, Bassarididæ, Mustelidæ, Protelidæ, Arcticidæ, Viverridæ, Cynictidæ, Suricatidæ, Cryptoproctidæ, Nimravidæ, Felidæ, Hyænidæ ; (*Pinnipedia*) ; Phocidæ, Otariidæ, Odobænidæ.

CHALICOTHERIA ; Chalicotheriidæ.

TAXEOPODA ; (*Condylarthra*) ; Phenacodontidæ, Pleuraspidotheriidæ, Meniscotheriidæ ; (*Litopterna*) ; Proterotheriidæ, Macraucheniidæ, Astrapotheriidæ ; (*Hyracoidea*) ; Hyracidæ ; (*Daubentonioidea*), Chiromyidæ, Mixodectidæ ; (*Quadrumana*) ; Adapidæ, Anaptomorphidæ, Tarsiidæ, Lemuridæ, Hapalidæ, Cebidæ, Cercopithecidæ ; (*Anthropomorpha*) ; Simiidæ, Hominidæ.

TOXODONTA ; (*Typotheria*) ; Atryptheriidæ, Interatheriidæ, Protoxodontidæ, Mesotheriidæ; (*Barytheria*); Xotodontidæ, Toxodontidæ.

PROBOSCIDIA; Dinotheriidæ, Elephantidæ.

AMBLYPODA; (*Taligrada*); Periptychidæ, Pantolambdidæ; (*Pantodonta*); Coryphodontidæ; (*Dinocerata*); Uintatheriidæ.

DIPLARTHRA; (*Perissodactyla*); Lophiodontidæ, Triplopodidæ, Cænopidæ, Hyracodontidæ, Rhinoceridæ, Tapiridæ, Lambdotheriidæ, Menodontidæ, Palæotheriidæ, Equidæ; (*Artiodactyla;*); Trigonolestidæ, Eurytheriidæ, Anoplotheriidæ, Dichobunidæ, Cænotheriidæ, Anthracotheriidæ, Xiphodontidæ, Suidæ, Hippopotamidæ, Merycopotamidæ, Dichodontidæ, Oreodontidæ, Poebrotheriidæ, Protolabididæ, Camelidæ, Eschatiidæ, Tragulidæ, Moschidæ, Bovidæ, Cervidæ.